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UNIVERSAL INFANTRY WEAPONS TRAINER (UIWT). VOLUME 1. M-16 RIFLE--ETC(U)
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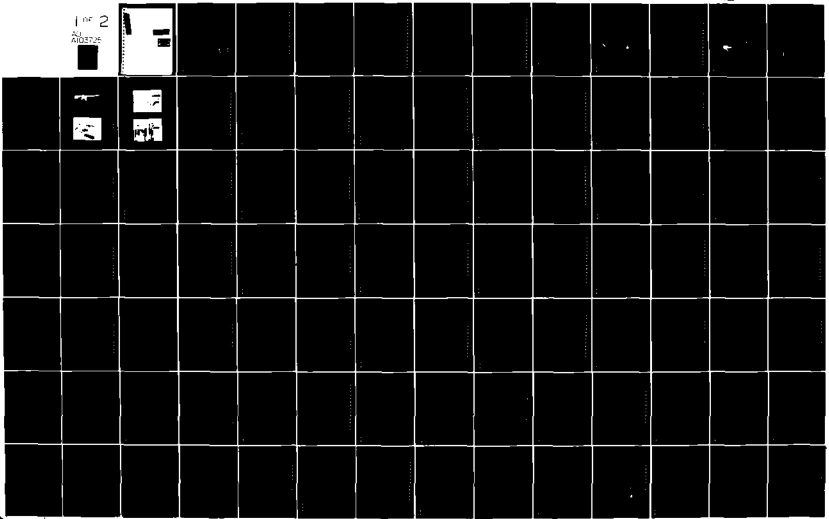

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The Universal Infantry Weapons Trainer (UIWT) is an electro-optic based, micro-computer controlled, training device that enables tactical infantry weapons training with a M-16 rifle, under a simulated high stress battle field environment. The battlefield is simulated using a 16mm movie. A receiver on the weapon is used to detect kill, near miss or miss information. The following weapons effects and feedback are provided the trainees or instructor: weapon recoil, weapon bang, magazine action, automatic or single shot, lead and elevation if

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applicable, audio scoring feedback using a computer generated voice, reaction time measurement, movement of weapon and a hard copy score.

SUMMARY

The Universal Infantry Weapon Trainer (UIWT), is an electro-optic based, microcomputer controlled, training device that enables tactical infantry weapons training with an M-16 rifle and 16mm motion picture projectors which simulate a high stress battlefield environment. In a short period of time a trainee can be subjected to a large variety of combat situations where each trainee's performance is analyzed in real-time and immediate feedback is given to both the trainees and instructor. Combat scenarios can be changed to fit any potential battlefield requirement. Prototype models were constructed by the Research and Technology Department, NTEC, Orlando, Florida for both the U.S. Marine Corps and PM TRADE. These models were successfully tested at Camp Lejeune, North Carolina by the U.S. Marine Corps and by the U.S. Army Infantry Board (USAIB) for the Directorate of Training Developments, U.S. Army Infantry School, Fort Benning, Georgia. It was stated that the tests did give some evidence of the UIWT system's potential for training transfer (Ref. 9). Furthermore, enlisted men, snipers and a variety of General, Field and Company grade officers who fired and observed the UIWT stated that it was a valuable training tool (Ref. 8).

U.S. Marine Corps and PM TRADE sponsored work is continuing on this program to develop the capability to add other weapons i.e., Dragon, LAW, M-60 macine gun, etc.

The authors wish to thank the Acquisition Sponsors Project Officer, Major E. Hutchinson and Lt. Col. R. F. Zumbado, formerly Assistant Marine Corps Liaison Officer, for their aid and valuable suggestions.

TABLE OF CONTENTS

ILLUSTRATIONS

TABLES

SECTION I

INTRODUCTION

The Universal Infantry Weapons Trainer (UIWT) is an electro-optic based, microcomputer controlled, training device that enables tactical infantry weapons training with an M-16 rifle, under a simulated high stress battlefield environment. In a short period of time a trainee can be subjected to a large variety of combat situations where each trainee's performance is analyzed in realtime, and immediate feedback is given to both the trainees and instructor. Combat scenarios can be changed to fit any potential battlefield requirement. An artist's concept of the trainer is shown in Figure I-1.

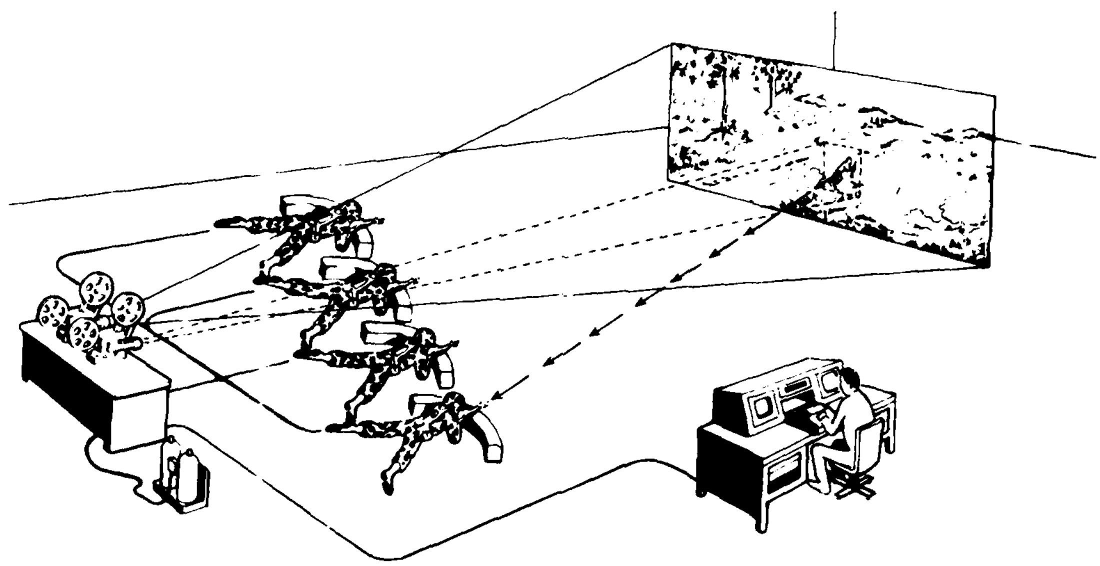


Figure I-1. Artist's Concept

This training device provides the trainees or instructor the following simulated weapons effects and feedback information:

- Weapon recoil
- Weapon bang
- Magazine action
- Automatic or single shot simulation

- Lead and elevation if applicable, is programmed in the system
- Real-time individual audio scoring feedback, using computer generated voice, via a headset
- Trainee feedback data displayed in columns on TV type monitor for instructor observation
- Reaction time
- Movement of weapon relative to correct kill zone is observed by instructor and recorded for playback.
- Lowest performer indicated to instructor
- Identification of trainee responsible for shooting with no target present
- Built-in self-check features
- Score determined
- Hardcopy of scoring results

SECTION II

SYSTEM DESCRIPTION

This section of the report describes the system. Details of the system design are included in Section III.

The system utilizes two motion picture projectors: a visual and an infrared (IR) target spot projector (see Figure II-1). The visual projector displays the battle scene including the visual targets. The infrared projector provides invisible infrared target areas at which the weapon must be aimed in order to score a hit. Lead is programmed into the infrared target film, which the weapon receiver detects, requiring the trainee to lead the target as necessary. Figure II-1 shows the visual target on the left and the infrared target on the right indicating that the target is moving to the right.

Each trainee has a simulated M-16 rifle with an attached infrared (IR) receiver. The IR detector is a four-quadrant photodiode. The four-quadrant target information and microcomputer logic determines kills, eight areas of near misses, and total misses. The regions of near miss include high, low, left, right, high right, high left, low left, and low right.

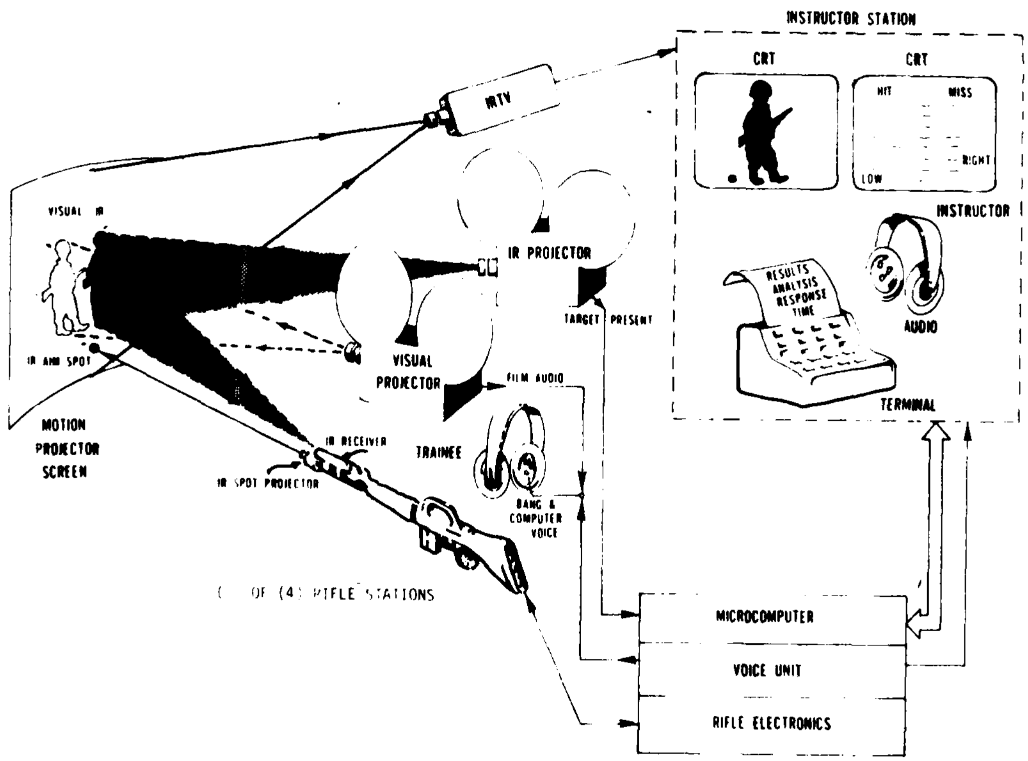


Figure II-1. System Block Diagram

When the trainee fires the weapon he hears a simulated bang and feels a recoil. Recoil is generated by a short pulse of air released near the front sight which drives the weapon high and to the right. An 8080 based microcomputer determines where the round would have hit using the detector's quadrant data and supplies this information to both a computer generated voice unit and a CRT display on the instructor's console. The computer voice unit drives both the trainee and instructor headsets. When a target appears on the screen, the IR projector outputs a target present signal from the magnetic audio stripe on the film. This signal starts a clock in the microcomputer which measures the time until the trainee fires, or effectively his reaction time. The target present signal is also used to determine the number of targets that appeared, targets ignored, targets shot at and if the trainee fired when no target was present. Trainee results are continuously displayed in columns on a CRT display on the instructor's station. At the completion of the exercise, the results, analyzes and response time are printed by a terminal at the instructor's station.

Distribution of fire can be monitored using a gallium arsenide laser infrared source located in the flash hider part of the rifle. The projected IR laser spot is invisible to the trainee but is detected by an infrared television camera and displayed by a CRT located on the instructor's console as shown in Figure II-1. When the rifle is fired the IR spot projector illuminates the screen with a small IR spot. If the instructor wants to continuously monitor rifle motion the IR aiming spot is left on continuously and the laser spot brightens when the trainee shoots. The TV camera data can also be recorded for playback during debrief.

Figure II-2 shows the rifle electronics and two projected targets. Discrimination of the infrared targets is enhanced by projecting the IR targets at frequencies different from the visual scene signals and amplifying the infrared targets. The motion picture projectors have also been modified to incorporate hot and cold mirrors, whose function will be described.

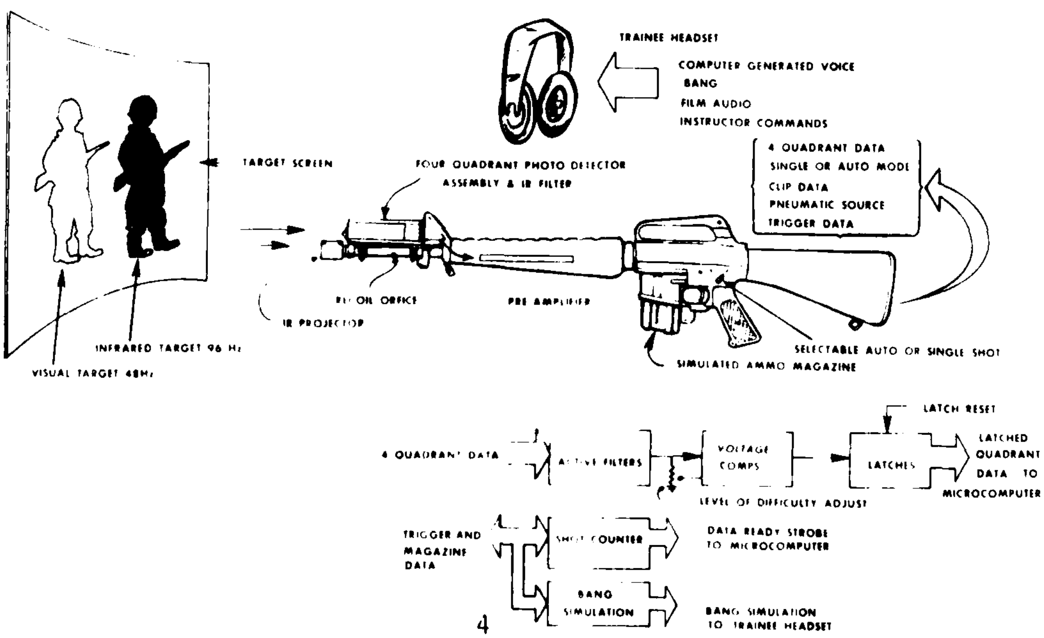


Figure II-2. Rifle Electronics Block Diagram

The visual projector contains a hot mirror. This multilayer dielectric mirror reflects or removes most of the infrared above 750 nanometer from the visual scene. The infrared projector contains a cold mirror. The cold mirror reflects the visual energy and passes the infrared energy above 750 nanometers. This allows a weapon equipped with an infrared receiver to ignore the visual data and obtain its target data from the infrared projector.

The S/N ratio of the system is further improved by using two different projector chopper frequencies. In the visual projector the chopper is a two bladed equally divided shutter. In the IR projector the chopper is a four bladed shutter. The visual scene is chopped or shuttered at a frequency of 48 Hz; the IR data is shuttered at a frequency of 96 Hz. By using two different chopping frequencies active filters in the weapons IR receiver can be tuned to detect the infrared target spot and ignore the visual battle scene. The projectors are frame locked together synchronously.

The rifle uses an IR detector consisting of a lens and a four-quadrant photo diode detector to detect infrared targets. An infrared filter is utilized in the weapon optical system to reduce the visual signal effect on the photo detector. The photo detector signals are amplified by two bi-FET operational amplifiers. A voltage comparator sets a threshold to establish a digital "one" or "zero". The voltage reference level of the comparator can be set to adjust the level of difficulty. The voltage comparator data is latched and delivered as input to the microcomputer system for data analysis, display and feedback.

The rifle can operate in either a single-shot or automatic mode and requires the trainee to reload after he has fired thirty rounds. The rifle's simulated magazine contains a capacitor. When the magazine is inserted into the rifle this internal capacitor is discharged, which resets a counter.

Bang simulation is achieved by filtering a noise source and then producing a noise envelope with a sharp rise time and exponential decay.

The training rifle is shown in Figure II-3. The four-quadrant detector is located on top of the barrel and the flash hider contains a gallium arsenide IR laser. The rifle is a replica but contains real sights that are adjustable. The plastic hose shown attached to the rifle, Figure II-3, is used to carry the air for recoil.

The instructor's console is shown in Figure II-4. The right hand CRT displays the verbal data transmitted to each trainee in four columns. The lowest score is automatically flagged by a LED under the applicable trainees column. This alerts the instructor so he can more closely observe that trainee. The left hand side of the console contains a CRT display used to monitor the weapon motion. Communication to the microcomputer is via a terminal shown in front of the instructor. See Appendix E for description of the switches on the console.

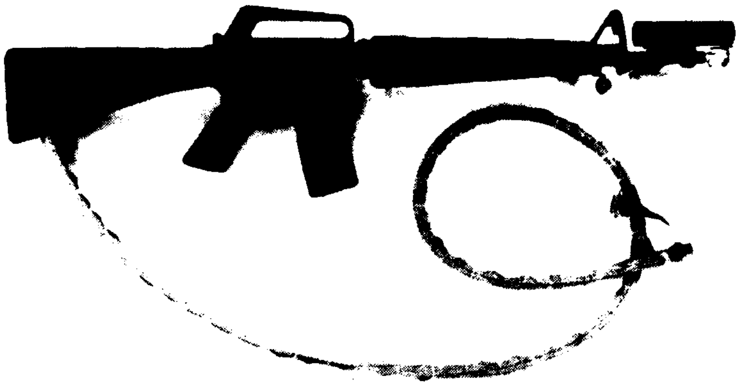


Figure II-3. M-16 Training Rifle

Figure II-4. Instructor's Console

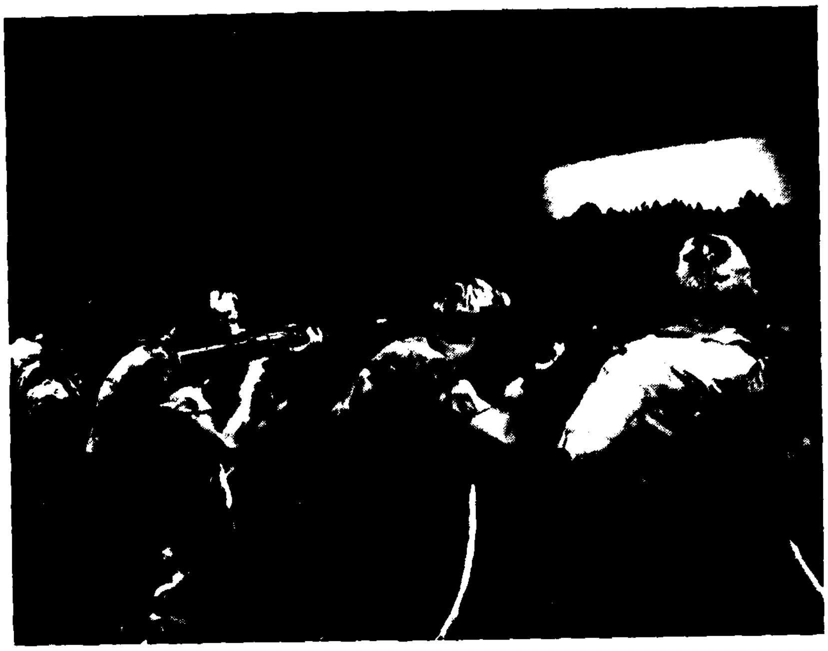


Figure II-5. Trainees Firing at Screen

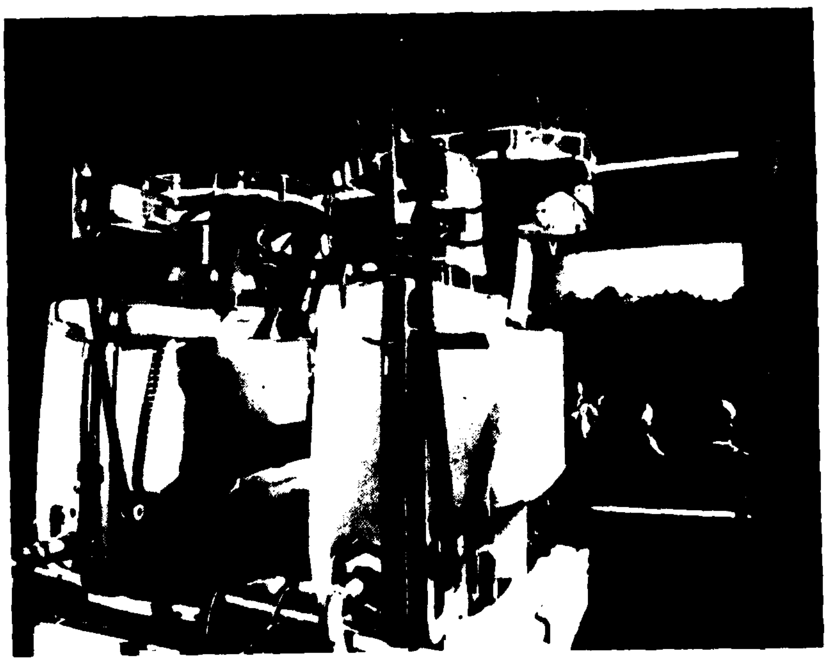


Figure II-6. Synchronized Visual and IR Projectors

Figure II-5 shows the trainees firing at the screen. Note each trainee wears a headset for individual feedback.

Figure II-6 shows the projectors. Loopers (a closed-loop film strip) are used so rewinding is not necessary. An auto-stop/auto-align feature is visible near the loopers.

The computer voice system is a solid state communications processor. It operates as a standard data terminal to the host 80/20 microcomputer system. The vocabulary has been digitized and stored in nonvolatile memory (PROM). The system contains thirty-two individually addressable words and five independent output channels. Thus, the computer voice system can talk to any or all of the five trainees while saying the same or different words or phrases. Each trainee wears a headset so he hears only the feedback applicable to his performance.

The system is controlled by a modified Intel 80/20 microcomputer system.

Section III, next, describes the system design.

SECTION III

SYSTEM DESIGN

A. PROJECTORS

The motion picture projectors are two Hokuskin, 16mm sound projectors equipped for frame-for-frame sync. The lamp is a 500 watt Xenon-arc, type KXL-500H. One projector is used as an IR target spot projector. The IR projector uses a cold mirror to remove the visual energy, Melles Griot, 03MHGD07. The transmittance of the hot and cold mirrors are shown in Figure III-1.

Loopers are utilized instead of reels to eliminate the necessity of rewinding the film.

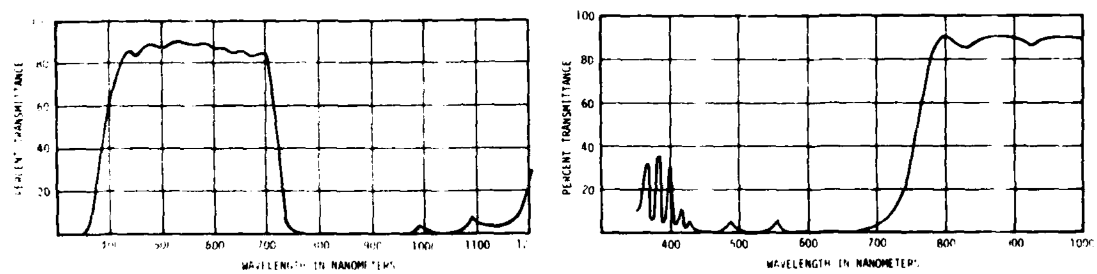


Figure III-1. Transmittance of Hot and Cold Mirrors

The projectors are equipped for either optical or magnetic sound reproduction. Sound for the battle scene is recorded for optical pickup on the visual projector.

Target present signals are recorded on the magnetic stripe of the IR film. The target present signal is a 1 KHz audio tone, which is decoded by an electronic tone decoder, Figure III-2.

The battle scene film was both taken and projected using a 25mm focal length lens to minimize perspective distortion.

The IR projector has a modified four bladed shutter which chops the IR data at a frequency of 96 Hz. The visual projector has a conventional two bladed chopper which chops the visual scene at 48 Hz.

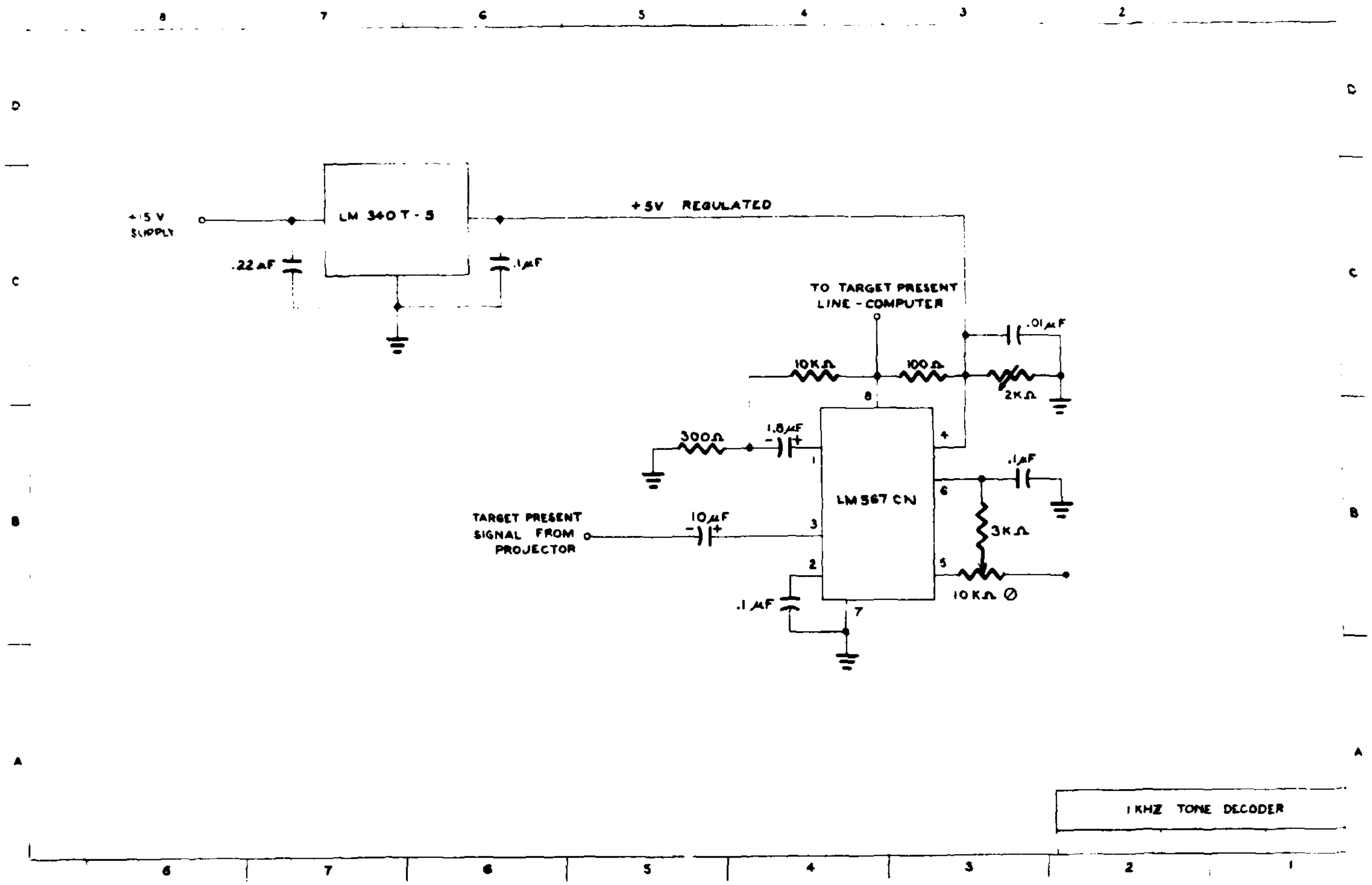


Figure III-2. Target Present Decoder

The projectors are equipped with an auto-stop feature which allows the film to be stopped at any desired location by simply placing a foil metal strip on the desired stop location.

The screen is silver matte, 9 ft x 12 ft overall.

B. RIFLE ELECTRONICS

The rifle electronics detect the IR target spot, amplifies, discriminates and provides digital data to the 8080 based microcomputer.

The detector optics is a single element double convex lens, with a diameter of 29mm and focal length of 114mm.

The IR detector is a four-quadrant silicon photodiode. This device consists of four discrete elements on a single substrate with an active output lead from each element. When the weapon is aimed properly the infrared target spot is centered on the detector and the output current from each quadrant is equal. As the rifle is moved the currents change as a function of the location of the infrared target spot on the detector. Imbalance in the current indicates off-center position. The detector has an active area of 0.05" x 0.05" per element with a gap of 0.005" between elements. The detector physical geometry and spectral response is shown in Figure III-3.

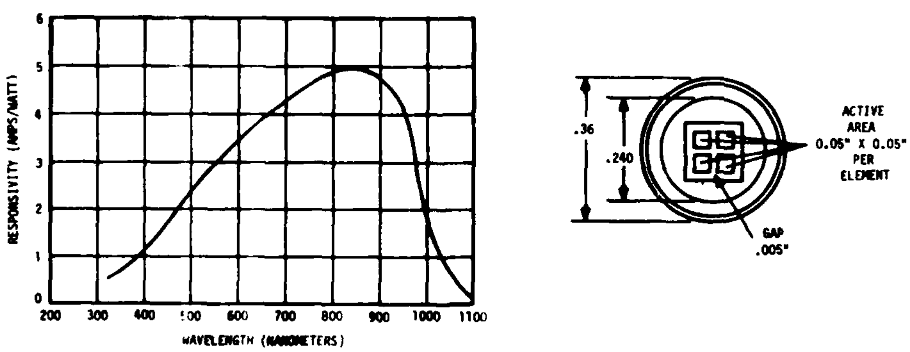


Figure III-3. Photo Detector Spectral Response and Geometry

The field of view of the IR detector is approximately seven inches on the screen.

The currents from the diode are input to an operational amplifier, TL082. The photo diode detector is basically a current source with an output impedance which is very large. The first stage of the current-to-voltage converter presents almost zero load impedance to ground because the inverting input appears as a virtual ground. The input current from the diode flows through the two Megohm feedback resistor, generating an output voltage.

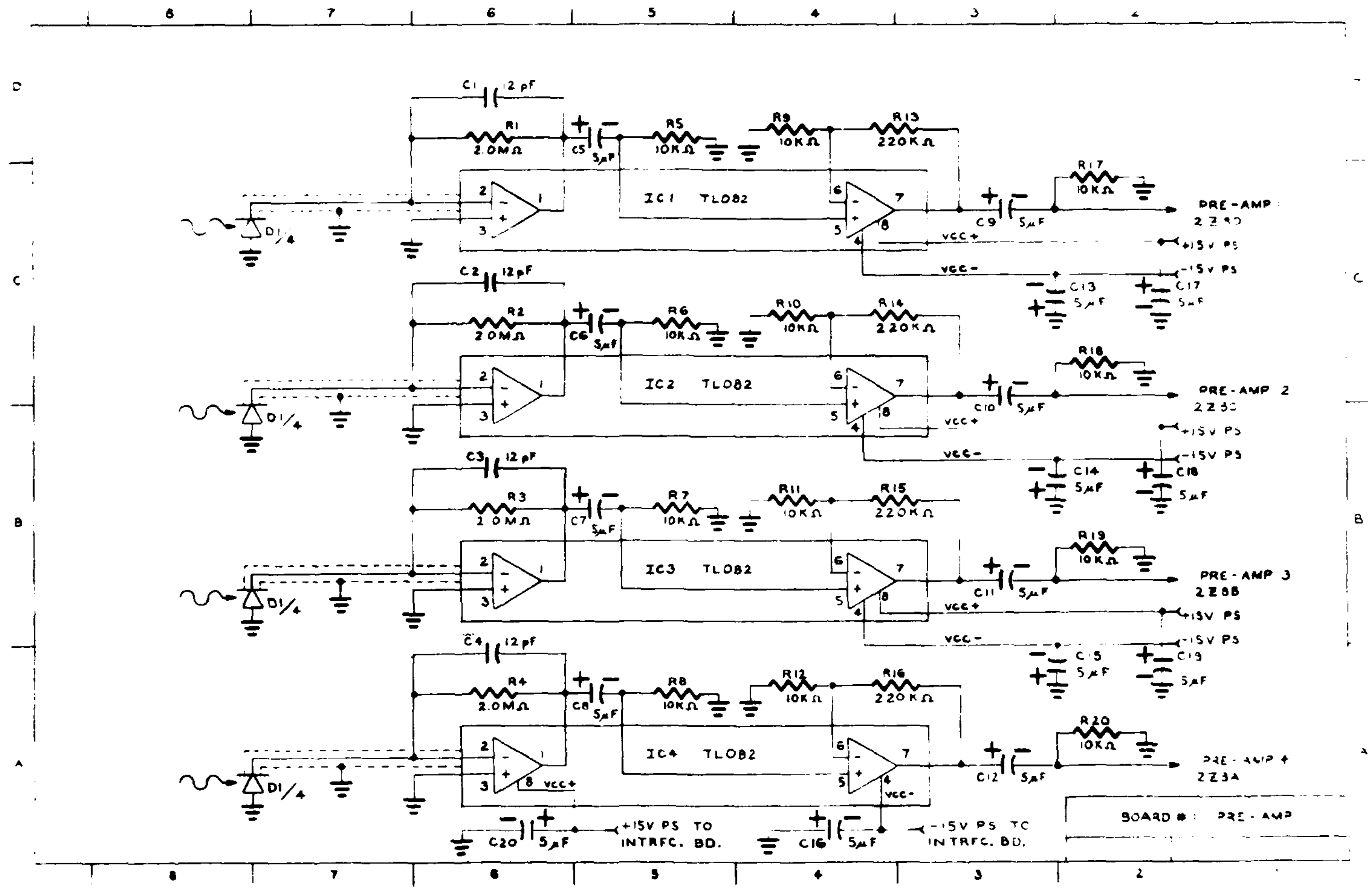


Figure III-4. Pre-Amplifier - Rifle Electronics - Board #1

$$\text{voltage}_{\text{out}} = i_d R_f$$

where

R_F = 2 Megohm

i_d = detector current

A separate channel is used for each of the four quadrants. The output from the current-to-voltage amplifier goes to a noninverting amplifier with a gain of 23. This stage is also part of the TL082. The electronics described above is located on Board #1, Pre-Amp. (Figure III-4)

Input signals to the active filter are 48 Hz from the visual scene, 96 Hz from the IR target spot and any extraneous light. The active filter is used to pass and amplify the desired IR signal at 96 Hz and reject all other signals.

The UAF - 41 is a two pole active filter. It uses three operational amplifiers in a double integrator feedback loop to generate two conjugate poles. Location of the poles in the complex plane, and thus the natural frequency and Q are determined by external resistors.

The equivalent configuration of this band pass filter is shown in Figure III-5. The filter is designed for a 96 Hz center frequency with both a Q and gain of 50.

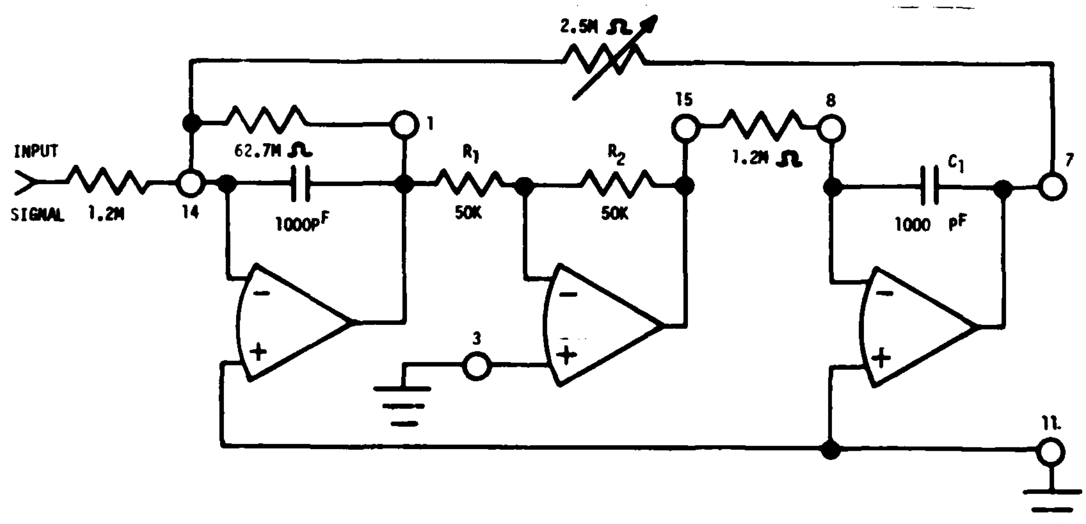


Figure III-5. Bi-Quad Active Filter

Both the active filters and voltage comparators are located on Board #2, Figure III-6. The output of the active filter is a sine wave with a frequency of 96 Hz. The output sine wave goes positive and negative about a zero volt reference level. This output is clamped and fed to a voltage comparator. The voltage comparator changes the analog detector signal to a digital signal. The input signal level for a one or zero is determined

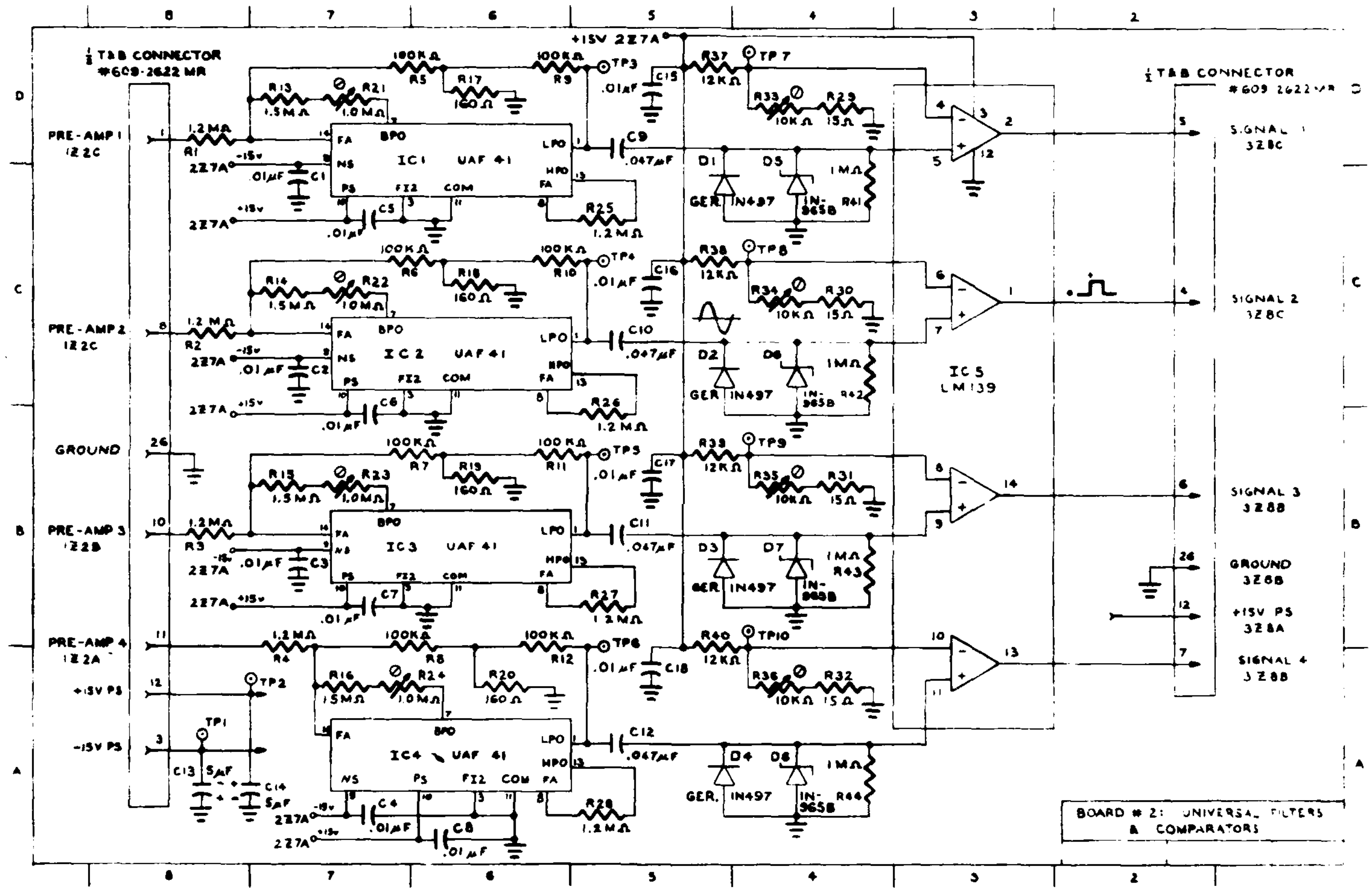


Figure III-6. Universal Active Filters and Voltage Comparators - Board #2

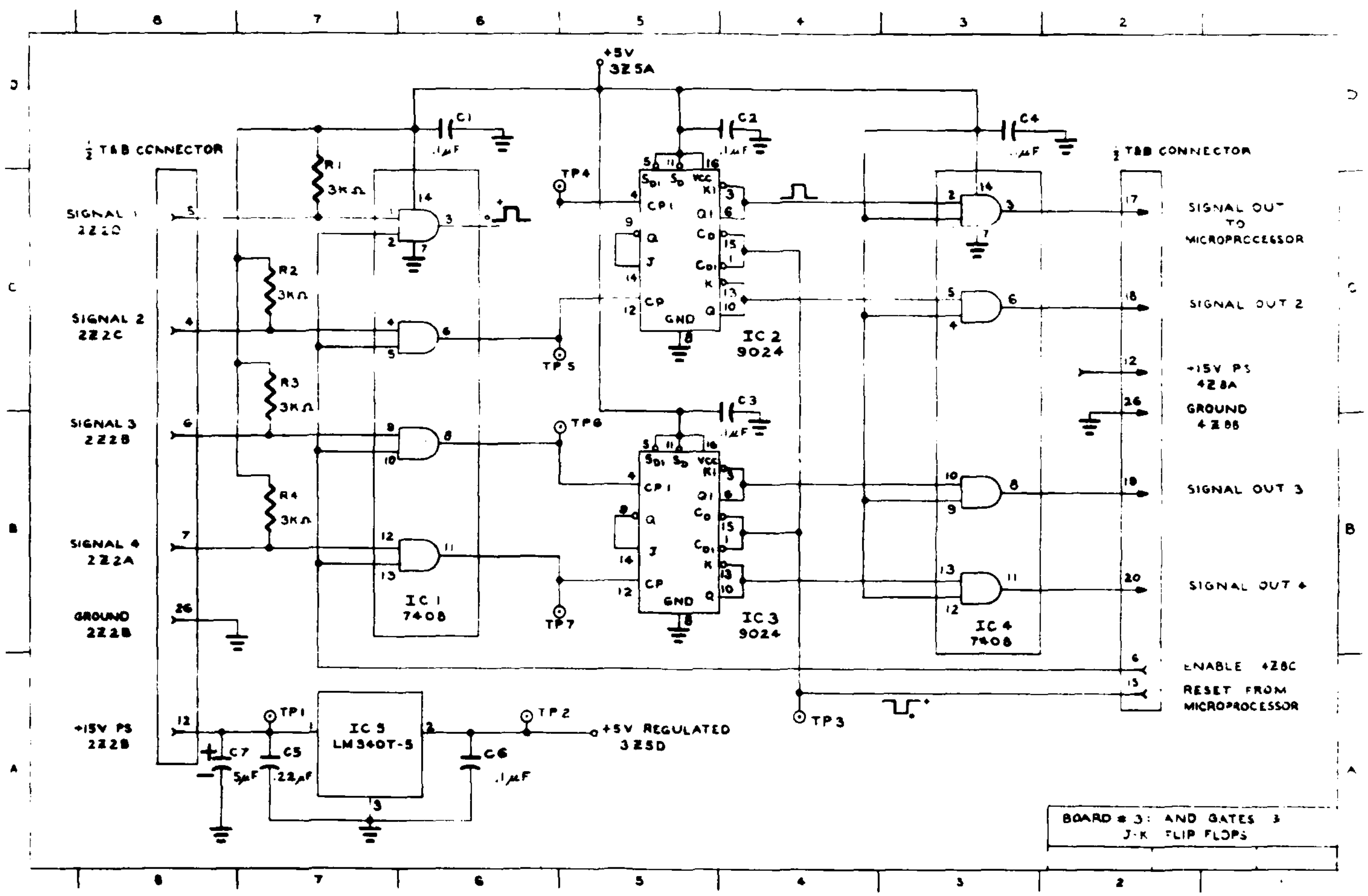


Figure III-7. NAND Gates and J-K Flip Flops - Board #3

by a resistor or reference voltage setting. Each of the four voltage comparator channels has its own reference voltage setting resistor, i.e., R33, R34, R35, and R36. The reference voltage setting controls the degree of difficulty in hitting a target. The detector signals next go to IC1, a 7408 AND gate, Board #3, Figure III-7. If the trainee pulls the rifle trigger and has rounds remaining in his magazine, the NAND gate is enabled by an input from Board #4. Board #4 is shown in Figure III-8. IC2 and IC3, Board #3 are 9024 JK flip flops configured as latches. Each 9024 has two latches. The 9024 is reset by the microprocessor after it has accepted the four-quadrant IR target spot data. IC4, Board #3 is a line driver.

Board #5, Figure III-9, is connected to the rifle trigger. IC1, a 5437, containing NAND gates, debounces the trigger and applies 5 volts to IC3. IC3, a timer, provides pulses of 12 Hz, which is the firing rate of the weapon. A one shot is also triggered and provides a single pulse. The output of Board #5 is determined by the setting of the single or auto fire switch on the simulated weapon. The setting of auto or single shot determines which gate on IC1 is active. If the trainee is in auto fire pulses at 12 Hz are provided Board #2. IC3 on Board #4 has a gate which will pass the signal if the counters IC1, IC2 on Board #4 indicate rounds are left. The counter enables IC1 on Board #3 and also enables the data ready pulse provided by IC4 on Board #4 to the microprocessor. IC4 is a one shot which generates a 10 μsec data ready pulse for the microprocessor to indicate data is available. After the microprocessor has read the data it resets the latches; IC2 on Board #3.

The one shot IC6, Board #4, Figure III-8, is used to reset the counters. The dummy magazine contains a capacitor. In the "loaded" configuration the capacitor is charged to 5 volts. The magazines are easily loaded or charged by momentarily inserting them into a charging fixture.

When the dummy magazine or capcitor is inserted in the rifle it discharges through R4, providing the counter reset voltage. The magazine is reloaded by charging the capacitor in the magazine to 5 volts.

C. COMPUTER VOICE AND AUDIO SYSTEM

The Computer Voice System is a Business Communicator Model LVM-70 manufactured by VOTRAX, the Vocal Interface Division of Federal Screw Works, Troy, Michigan. The LVM-70 was designed specifically to be used as a concentrator for touch-tone based information systems.

Up to 32 words (16 seconds) are available with up to eight audio output channels. The trainer utilizes an output channel for each trainer. When a shot is fired by a trainee the host computer (80/20) decodes the incoming rifle data and then sends three bytes of serial data to the LVM-70 specifying a start word, a trainee identification word, and the appropriate voice response code. The voice output line for each trainee is routed to the trainees audio mixer/amplifier, Board #6, Figure III-10, as well as the instructor's control panel.

The LVM-70 voice communicator can be replaced in later models for roughly 1/4 the original cost, due to technological advances.

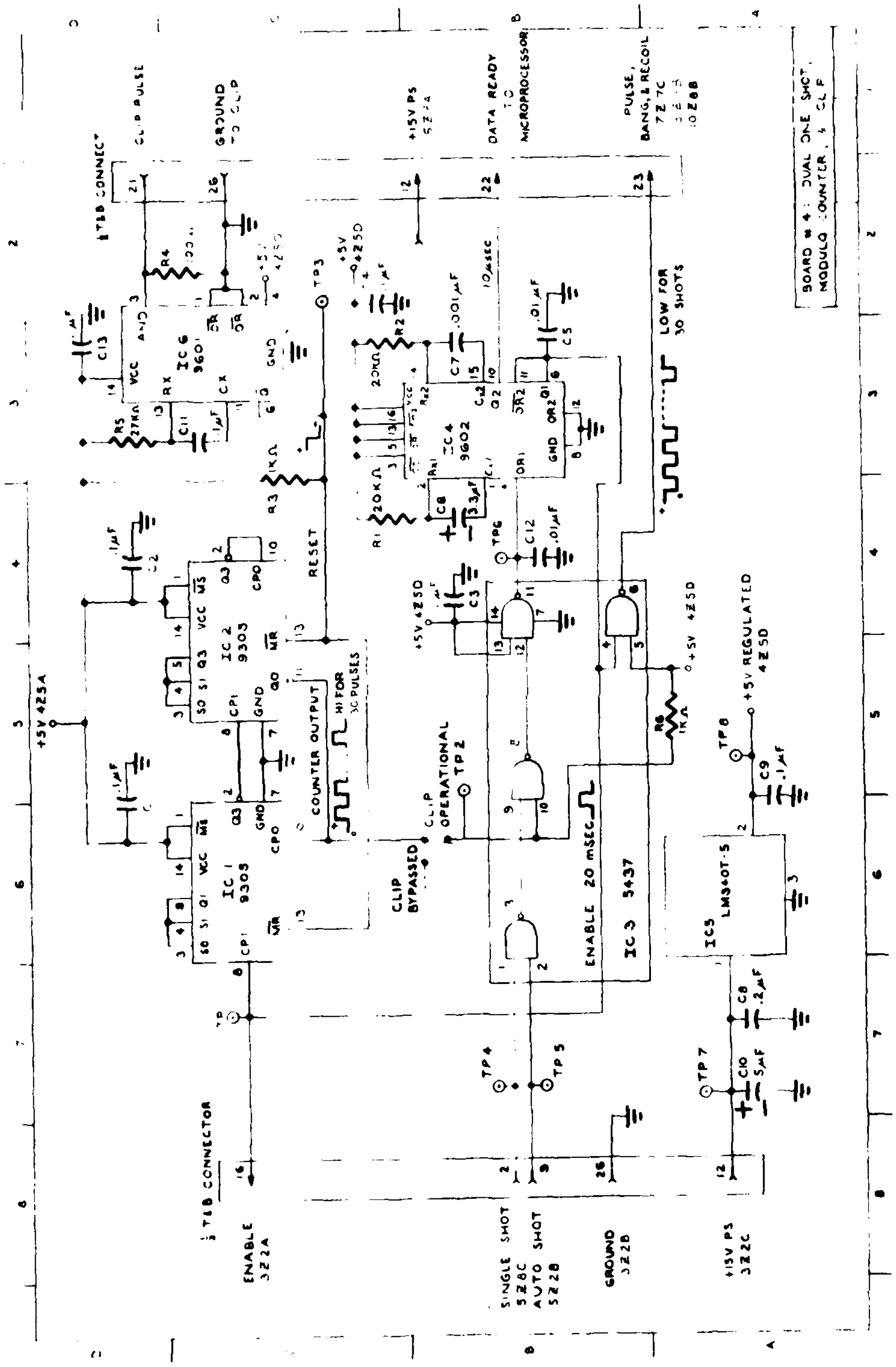


Figure III-8. One-Shot and Counters - Board #4

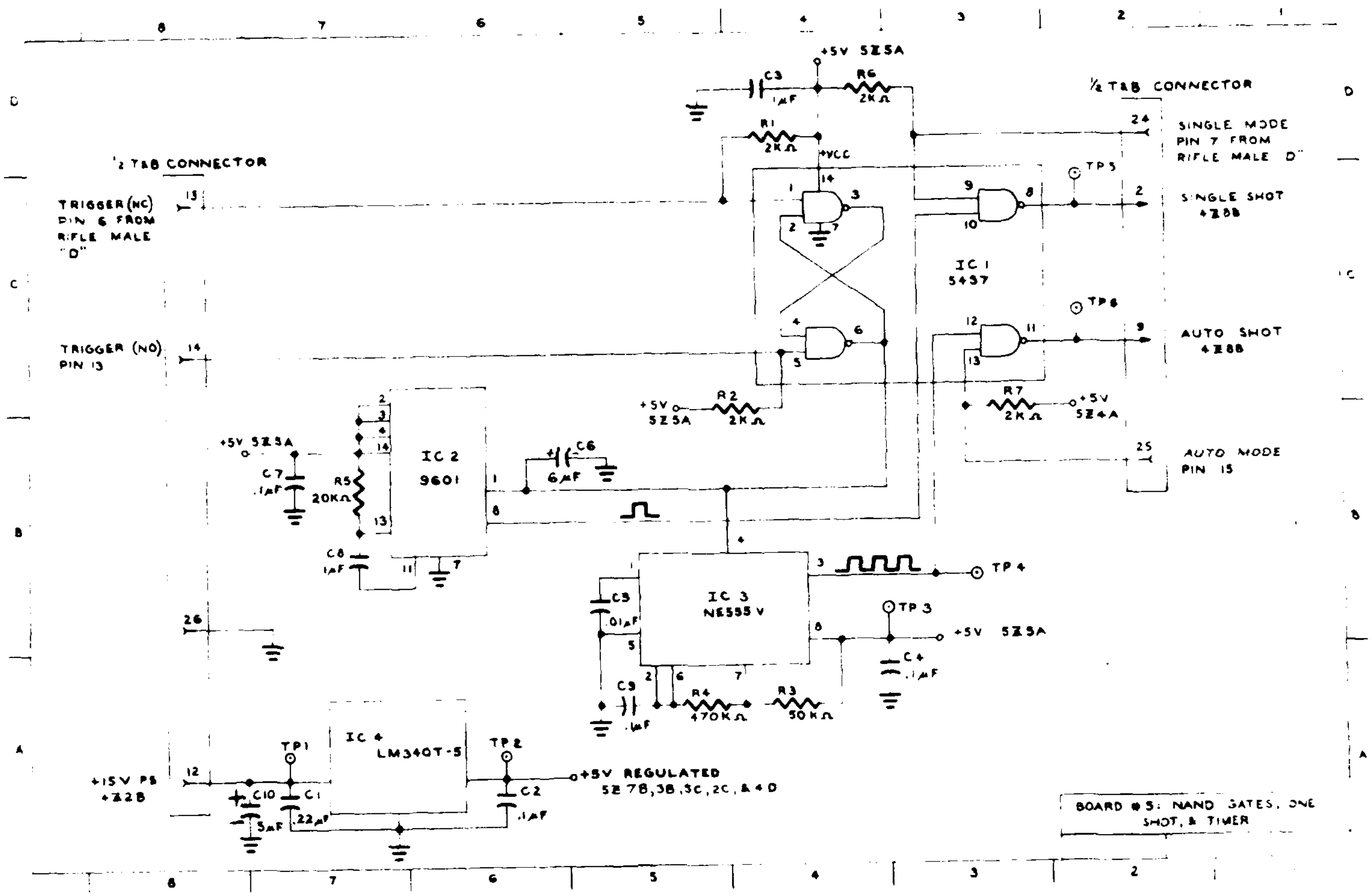


Figure III-9. NAND Gates, One-Shot and Timer - Board #5

Each trainee's audio system consists of two stages of audio amplification. A Texas Instrument's TL074 low noise, quad, dual operational amplifier, ICI, is used. Consequently, two trainees are handled by a single TL074 (Figure III-10). The first stage of amplification is primarily an audio mixer. Five independent channels are mixed into one. These five channels consist of the computer voice feedback system, the instructor communication line, the synthetic rifle bang, coordinated battlefield sounds and general battlefield environment sounds. The instructor uses an identical mixer/amplifier channel but his inputs consist of the various computer voice responses to the trainees. The instructor selects which trainee he desires to hear by pushing the appropriate switch on the instructor control panel.

Each of the five inputs to the mixer stage as well as the final output stage have their own volume control.

D. BANG AND RECOIL SYSTEM

1. BANG SYSTEM

An electronic bang is presented to the trainee via his headset when he has fired a shot. The bang board, Board #8, Figure III-11, produces the synthetic gunshot sound and passes this sound to the trainees audio mixer/amplifier Board #6, Figure III-10. The bang is produced by generating random noise, due to diode D1 being biased near its breakdown voltage, and then using the FET to generate an envelope for this random noise. This envelope consists of a sharp rise time and an exponential decay which corresponds closely to a gun shot noise envelope. Specifically, the diode D1 produces random noise which is amplified by 1/2 of IC1, a dual operational amplifier. This amplified random noise is presented to the drain of the FET. The FET does not pass this noise until its gate is presented the sharp rise and exponential decay envelop representing an actual rifle shot sound envelope. The sharp rise of voltage on the gate of the FET is produced by IC2 changing to a high state; 5 volts. When IC2 changes back to a low state, Ø volts, the diode D2 isolates the gate of the FET from being pulled down to an off state and allows the RC network consisting of R6, R12, and C7 to exponentially decay the residual voltage thus producing decaying gunshot envelope of noise. The source of the FET thus produces on demand random filtered noise within an envelope resembling a gunshot bang. The second half of IC1, an operational amplifier, produces final amplification of this sound before passing the output to the students audio mixer/amplifier.

2. RECOIL SYSTEM

The recoil system consists of three major parts: air hose, recoil board, and the air valve.

The air hose follows the electrical cable up to the rifle and into the butt of the weapon. The hose is a lightweight, nylon reinforced, dimentionally stable air line hose. After entering the butt of the rifle it runs forward and attaches to the rifle barrel. The barrel is plugged at the tip end and an outlet orifice has been drilled on the bottom of the barrel near the tip end. The orifice is pointing down and 30 degrees to the left which produces a thrust up and to the right when a shot is fired.

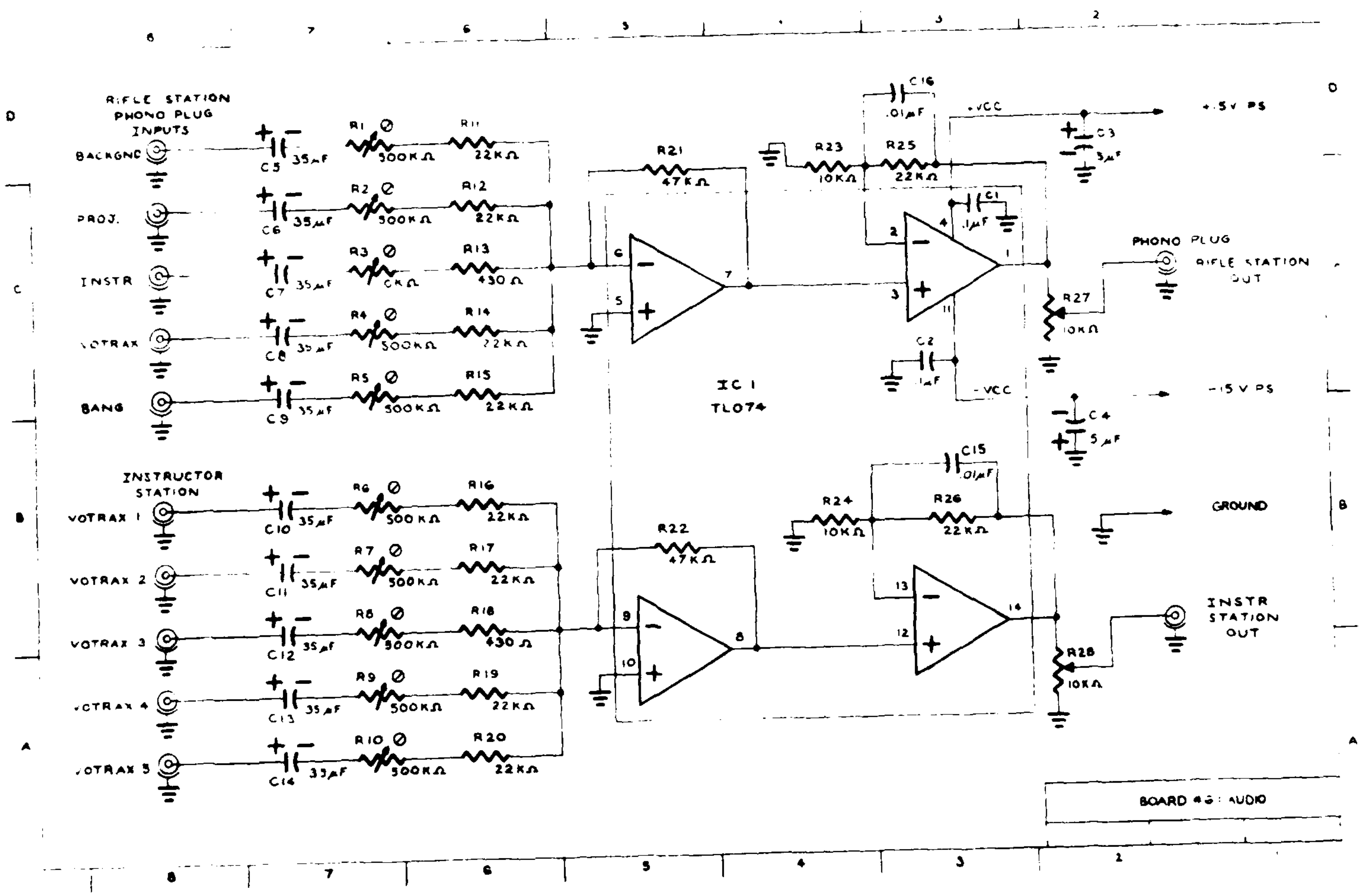


Figure III-10. Audio Amplifier - Board #6

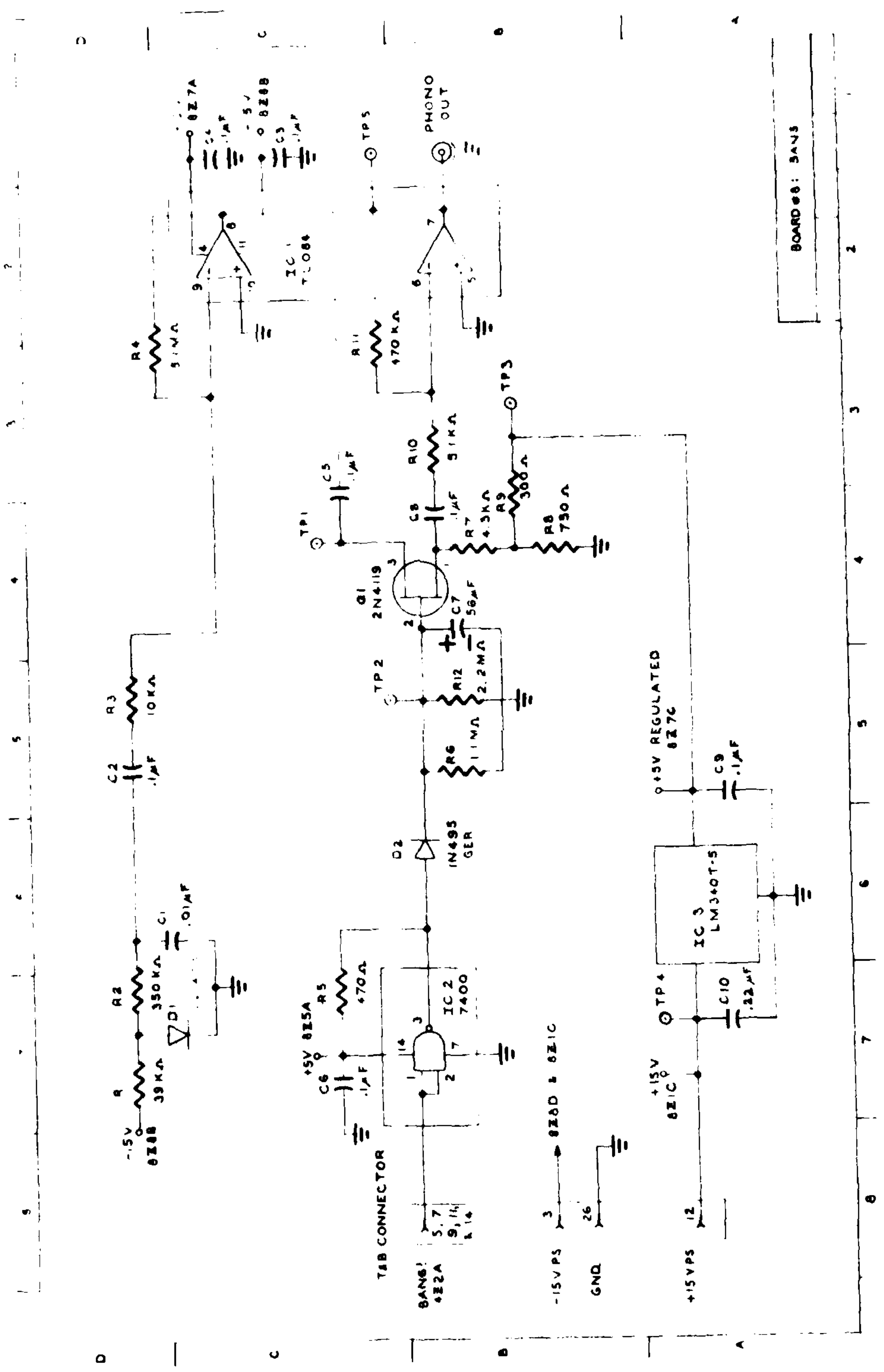


Figure III-11. Bang Simulation Generator - Board #8

The recoil circuit, Board #7, consists of a 555 integrated circuit timer, IC2, and a darlington pair transistor driver circuit for the recoil air valve. The 555 timer is set for a nominal 20-25 msec duration. The variable resistor R2 serves to regulate the timing duration (Figure III-12).

The recoil valve is a pilot operated solenoid valve. Because it is pilot operated, the on-off rise and fall times for actuation are very short and power consumption is only 8.5 watts.

E. DISTRIBUTION OF FIRE AND WEAPON MOVEMENT MONITORING

Distribution of fire and weapon movement can be monitored and recorded during a training exercise for playback. The system allows the instructor to view where the weapon is aimed relative to the IR target spot. This feature is completely independent of the basic system.

An IR light source is used on the weapon. The infrared light source used in the system is a semiconductor, gallium arsenide laser. The laser is collimated by a simple plano convex lens. The laser is attached where the weapon flash hider is located. If the instructor wishes to view the location of the trainees weapon, he selects the laser he wants turned on and holds down a button on the instructor's console. The instructor is able to view both the projector IR target and laser spot from the selected trainee's rifle. This information is detected using an RCA TC 1005/H01 low bloom silicon target Vidicon and closed circuit video equipment. The TV display tube is located in the instructor's console and the TV camera near the motion picture projectors.

The laser spot brightness seen on the TV is a function of the pulse repetition frequency (prf) of the gallium arsenide laser. Two modes are available:

- Flash only
- Track plus flash

In the flash mode only, a single flash occurs when the trainee fires. In the track and flash mode, the instructor sees a point of laser light on the screen all the time, which moves as a function of where the trainee is pointing; when the trainee fires, a brighter flash occurs.

Laser energy reflected off the screen is eye safe. However, the trainee should not point his weapon in another trainee's eyes as eye damage can occur from looking directly into the laser beam.

The laser timing signals are generated using Board #10, Figure III-13. The laser pulser, Board #11, is shown in Figure III-14.

The laser pulser uses a SCR, GA201 to discharge capacitor C1. Q1 is used to allow rapid recharge of Q1. The laser is a 5 watt peak power laser with a nominal 50 nanosecond pulse width.

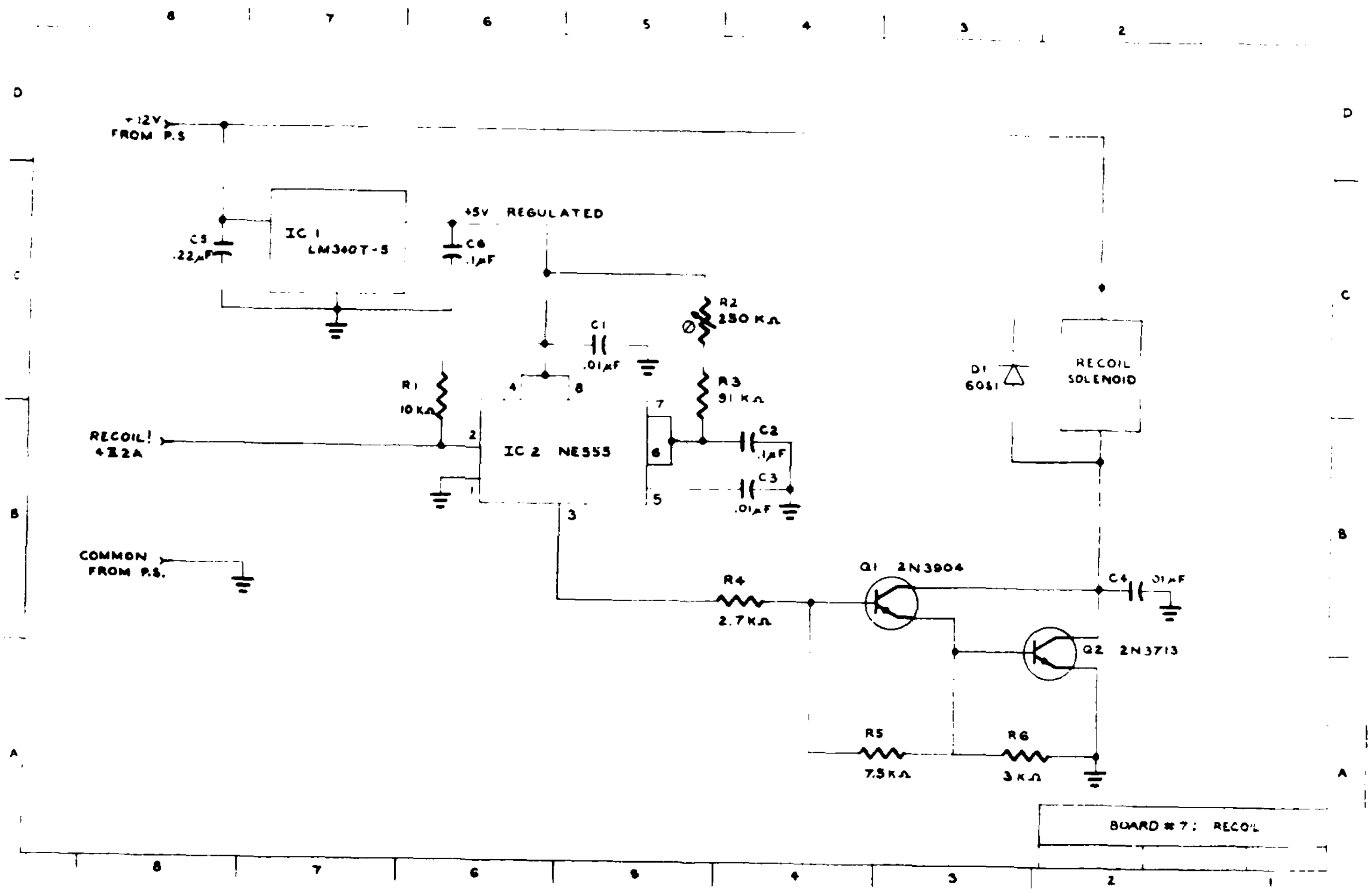


Figure III-12. Recoil Circuit - Board #7

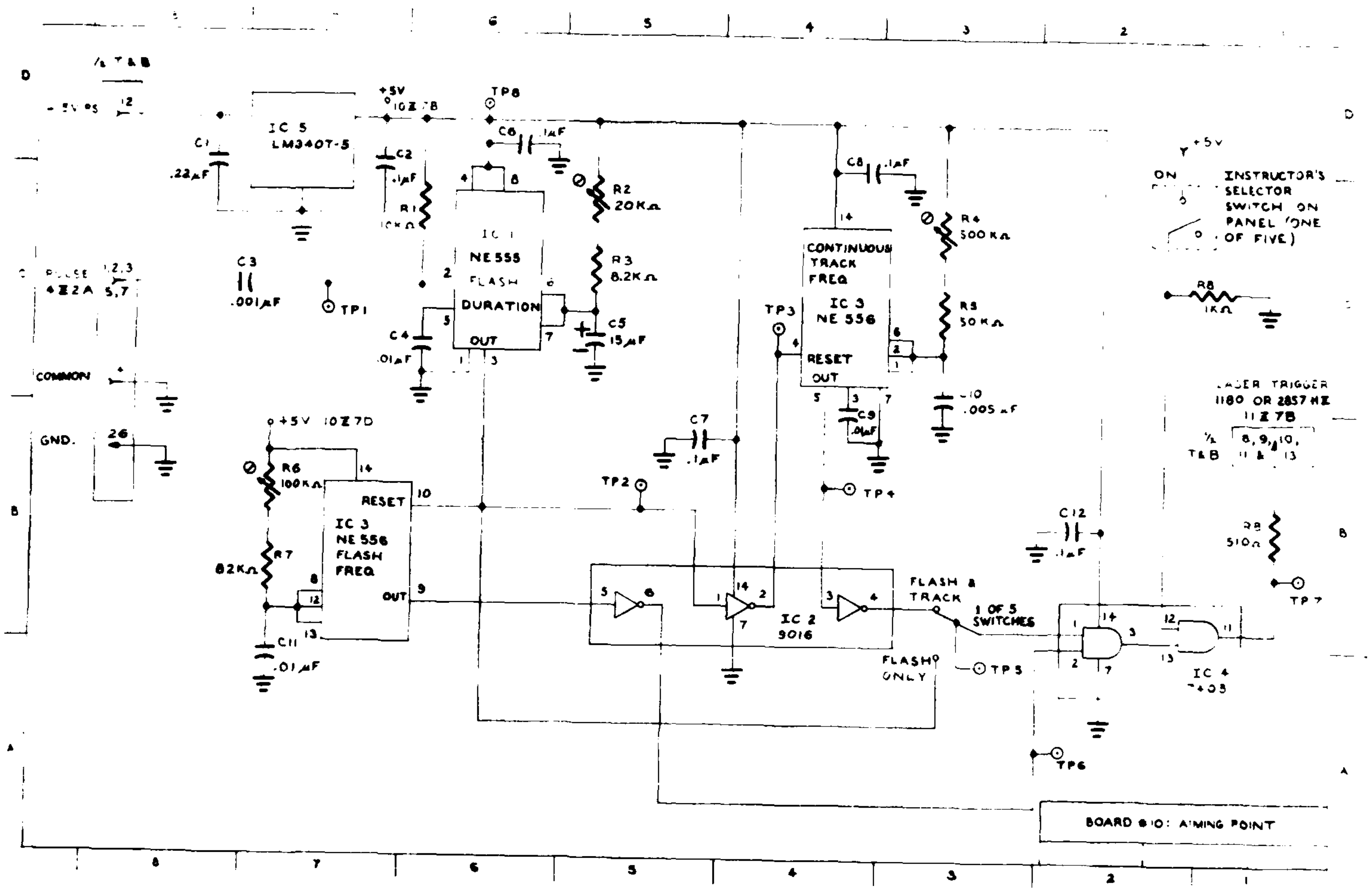


Figure III-13. Laser Signal Generation - Board #10

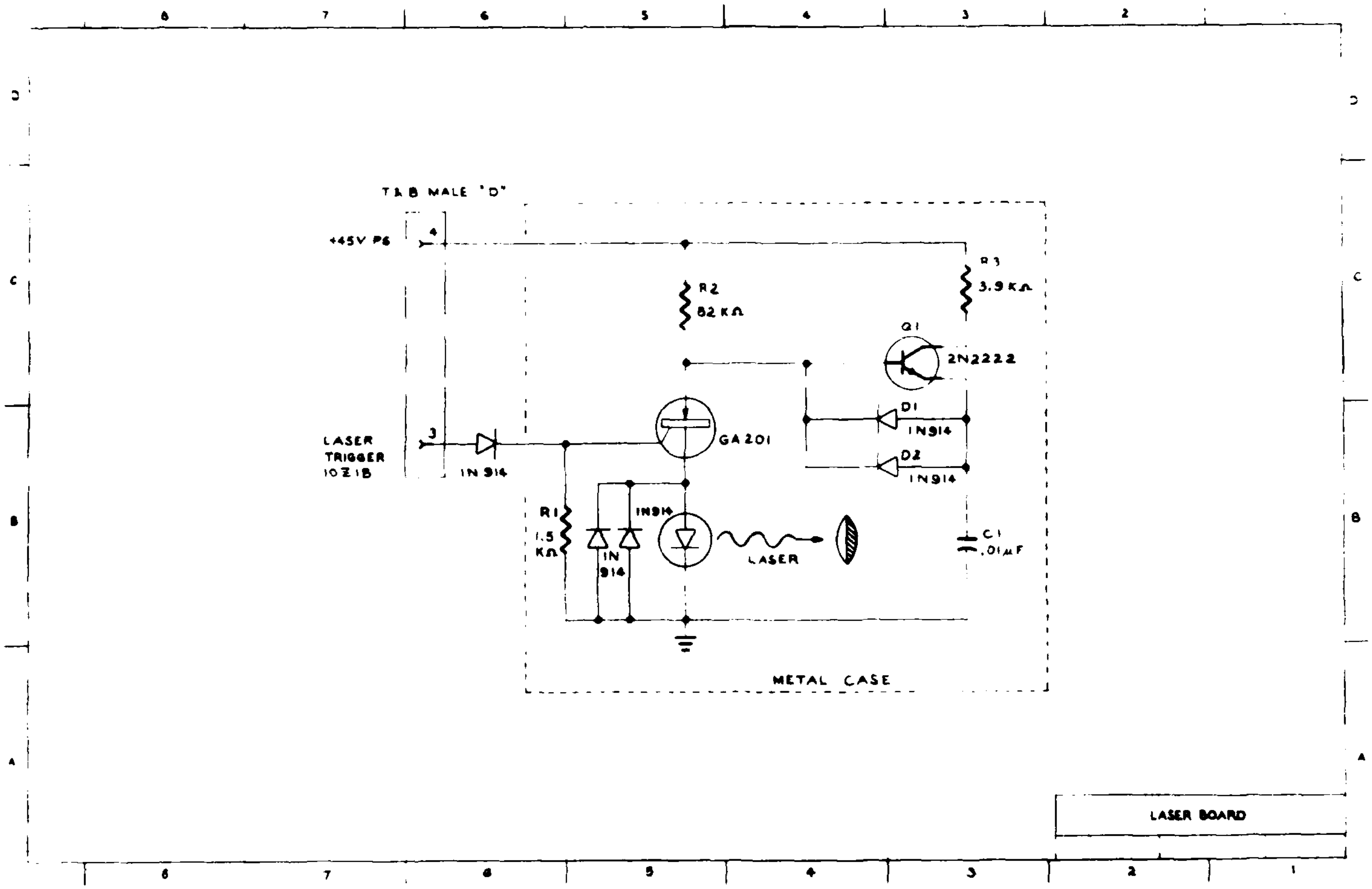


Figure III-14. Laser Pulser

F. RIFLE MOCKUP

The rifle mockup is manufactured by Replica Models, Inc. It is not designed to accept a round of ammunition and cannot be converted to accept ammunition. The original replicas received from Replica Models have been extensively modified to perform satisfactorily as a trainer. The original barrel plug was removed and moved to the front end of the barrel to accommodate the recoil. A recoil orifice was then machined and an electronic board was installed within the handguards. To accomodate boresighting, the original molded-on nonadjustable front and rear sights were replaced with adjustable front and rear sights. The mode selector switch was modified to reflect the real M16E1 mode positions; the trigger mechanism was modified for better performance; microswitches for the trigger and mode selector switch were installed; and magazine sensing contacts were installed for reloading simulation.

An optical four-quadrant detector and optics are mounted above the barrel and below the sights. A solid state laser and optics for point of aim information has been inserted in the flash hider position.

Air for the recoil and electronic wiring approach the rifle from the bottom rear of the butt of the rifle. The true weight of the M16E1 was restored by removing unused mechanism from the upper receiver. The true balance was maintained through equal weight additions, i.e., the detector/laser combination at the front end of the rifle offset the hose and electronic wire harness at the butt end of the rifle.

Special test equipment is included in Appendix B.

G. MICROCOMPUTER CONTROL SYSTEM

The 8080 Microprocessor Based Control System performs these functions:

- Interrogates the instructor for session parameters
- Stores session parameters for final hard copy
- Determines if self-check is desired, and reacts accordingly
- Initializes peripheral LSI chips and zeros memory storage
- Inputs rifle data, decodes and stores it
- Measures response time for first rifle shot at new target for each of four or five rifles
- Outputs shot results to audio feedback and instructor's CRT
- Identifies shooter making most errors and sends the identification to the instructor's console "LEDS"
- Updates shooter's results file

- Checks for session end and terminates the data collection mode upon the instructor's signal

- Computes trainee's overall score

- Prints trainee's results on the instructor's electronic data terminal

1. SINGLE BOARD COMPUTER

The UIWT System is controlled by a modified INTEL 80/20-4 Microcomputer System, Reference 6. This microcomputer system, which is based on the INTEL 8080 microprocessor, includes an enclosure with front panel controls, power supply, cooling fans, and a card cage in which is located the main 80/20-4 board as well as the interface board (IFB), which is described below.

a. 80/20-4 MODIFICATIONS

A number of modifications are required before the SBC 80/20-4 can be used in UIWT/SWAT Version 1.2. These are detailed below with page identifications to be found in Reference 6 unless otherwise noted.

(1) Pull-up resister packs, SBC-902, page 2-5, must be inserted in socket A5 and A6 as input terminators for port 2 at address E6. These terminators were supplied with the 80/20-4 systems as Beckman part number 1899-747-0, 3000645-01.

(2) Insert inverting line drivers, either #7437 or #7400, in sockets A3, A4, A9 and A10 for output ports 3 and 6 at addresses E6 and EA. See pages 2-4 and 4-24.

(3) Solder A jumper between J3-8 and J3-10 using the solder points on the rear side of the board. This connects "Request to Send" to "Clear to Send". See Table 2-5, page 2-7.

(4) Wire wrap A jumper from pin 1, a 5 volt source, near J3 pin #25 and solder it to a through hole just below "C9" between A15 and A16 on the front of the board. This should put 5 volts onto J3-16 "REC LINE SIG DETECT" which goes to the "DATA CARRIER DETECT" of the 743 TI terminal. Otherwise the terminal will not function. See page 27 of Reference 1.

(5) Change the wire wrap jumper which exists between pins 141-142 just above A22, the 8253, to a jumper between pins 141-143. This is an option which connects the clock input for counter 1 of the 8253 to the output of counter Ø. See page 4-21.

(6) Interconnect wire wrap pins 11 and 12 near the upper right hand corner of the board. These are the protect and signal grounds for the TI 743 terminal. See page 27 of Reference 1.

(7) Scratch through the line going from the transmit data (TXD), pin 19 of the 8251 USART, to the SN75188 (MC1488) line driver. Connect the 8251 side to J1-50 with a jumper wire and connect the driver side to J2-50. This allows the interface board to switch the serial output between the VOTRAX and the control console.

(8) Remove the jumper from wire wrap pins 52-53, located just below the left part of the leftmost 8255 and put a jumper between pins 51-52. This enables port 1 as an input. See Figure 5-2 (sheet 4 of 5). Check that a jumper exists between pins 71-72 to enable port 4 as an output.

(9) Connect the 80/20-4 front panel interrupt switch into the interrupt controller as interrupt #7. To do this, connect pins 36, 37, 38, and 39 together and also to pin #45.

(10) Make the required modifications to use 2716 2K byte EPROMS. These are given in Table 2-12, which is entitled "Jumper Changes For Optional 8K EPROM Installation". See page 2-15.

REMOVE	INSTALL	
W2, A-C	W2, A-B	Between A45 and A46
W4, B-D	W4, A-D	Above A78
W4, C-E	W4, B-E	Above A78
W7, A-B	W7, A-D	Below A79
W8, A-C	W8, A-B	Below A79
C35, 53 and 72		Above A37 and Below A64 and A79

2. THE INTERFACE BOARD

All input/output (I/O) operations of the SBC 80/20-4 microcomputer pass through the interface board (IFB). These operations can be divided into three categories.

- Rifle communications
- I/O through the 8751 "USART"
- Output through the UPI-41, 8741 Universal Peripheral Interface

Figure III-15 is a block diagram of these data paths and their associated control lines. More details are shown on Figure III-16 through III-19.

a. RIFLE COMMUNICATIONS

IR spot quadrant detector data are input from each rifle to a separate 8212 eight-bit input/output port chip on the IFB. A trigger-pull signal is also sent from each rifle to its associated 8212. Upon sensing a trigger signal, the quadrant data are latched into the 8212 buffer and an interrupt signal requesting service is output from the 8212 to the main board through input port 1. The service request lines from all five 8212s are "ORED" together onto a single line which also goes to port 1 to signal that at least one 8212 requires service. AS long as this ORED line indicates a service need, the microcomputer polls each 8212 service request line in turn. When one is detected that needs service, the address of the 8212 responsible for the request is output from port 3 on the main board to a 9311 one-of-sixteen decoder on the IFB. A data read signal is then output from port 6 to the 9311, which commands the 8212 to place the contents of its latched buffer on the common data bus.

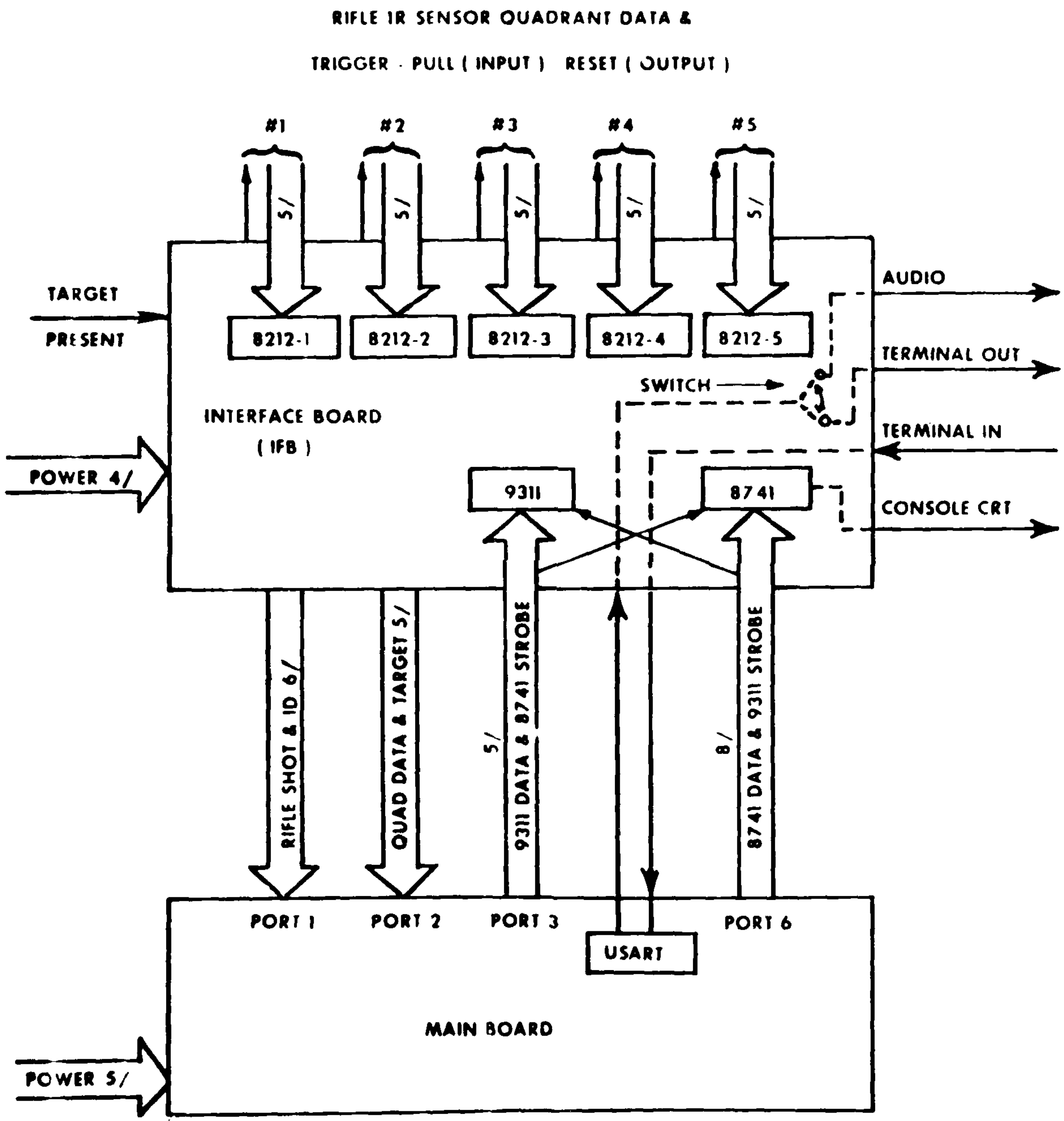


Figure III-15. 80/20-4 Main and Interface Boards

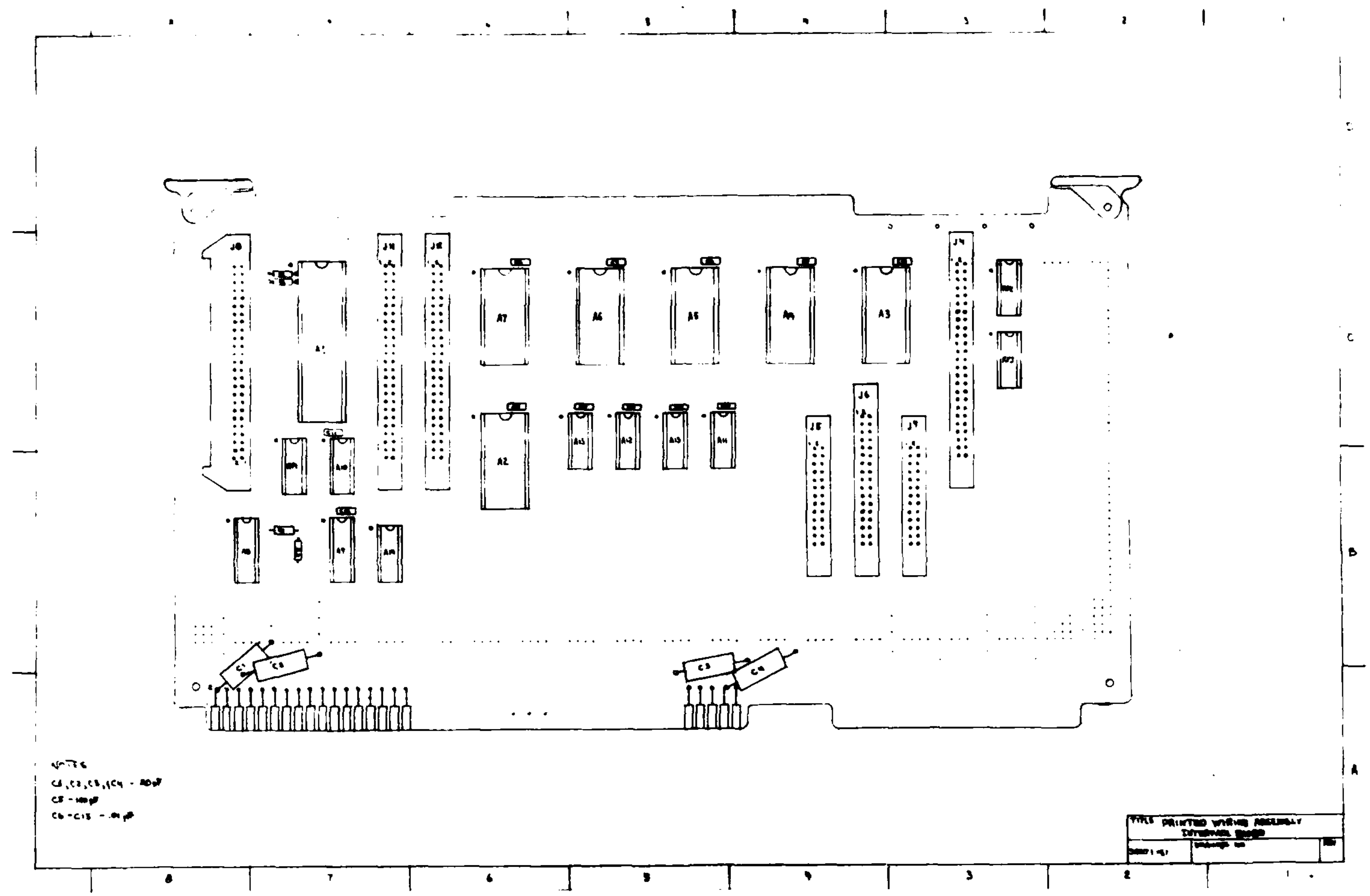


Figure III-16. Interface Board Layout

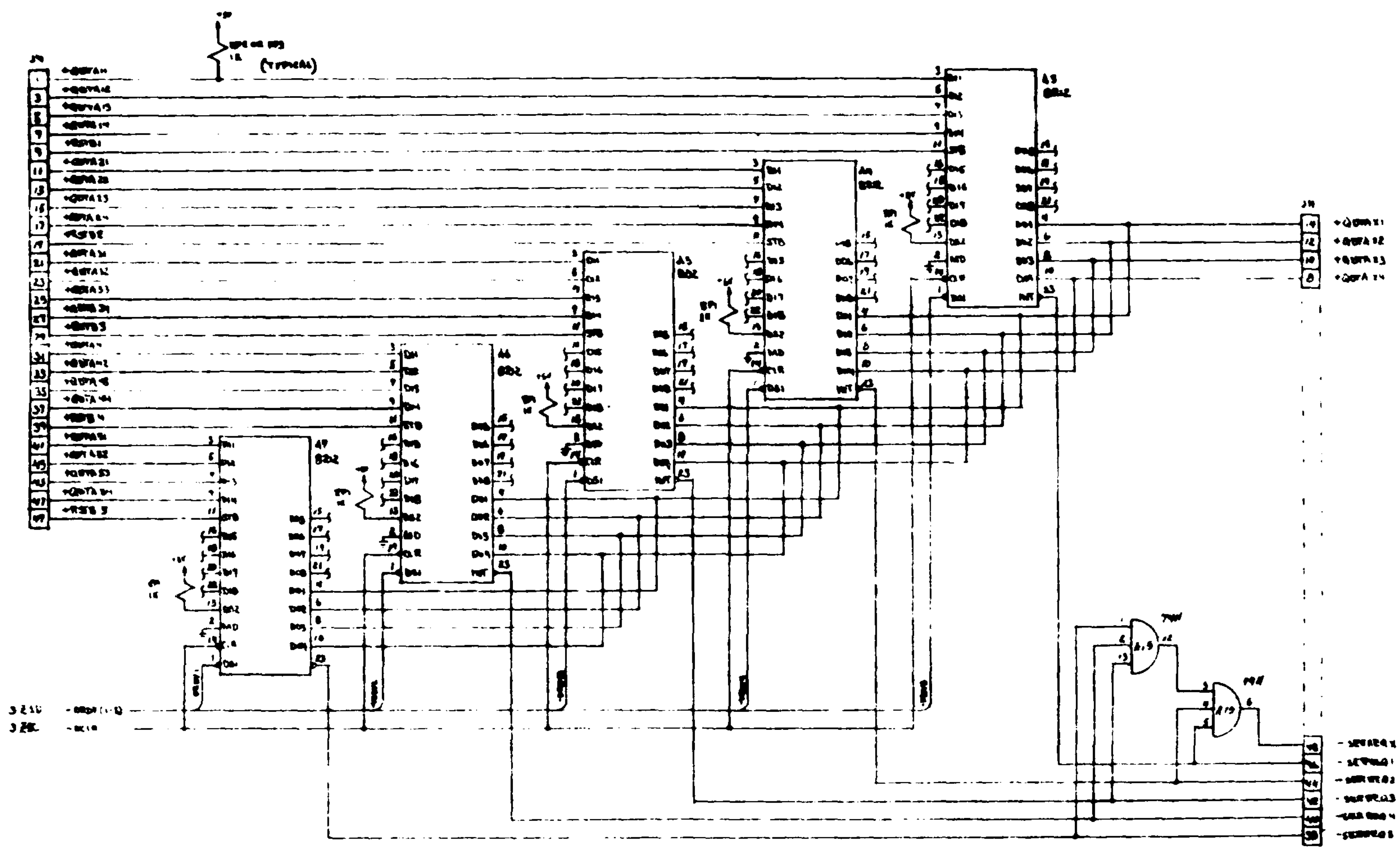


Figure III-17. Interface Board Schematic (1 of 3)

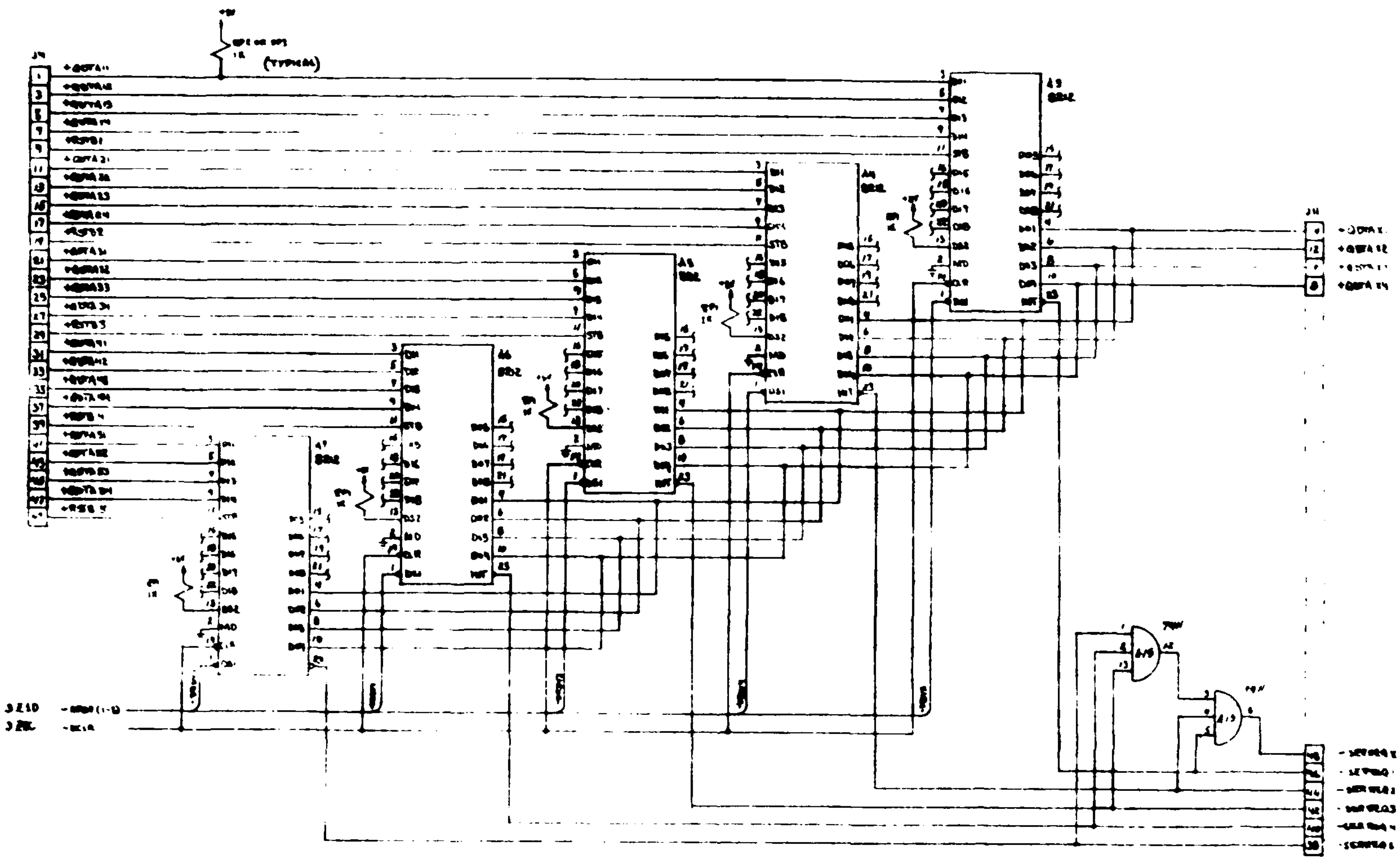


Figure III-18. Interface Board Schematic (2 of 3)

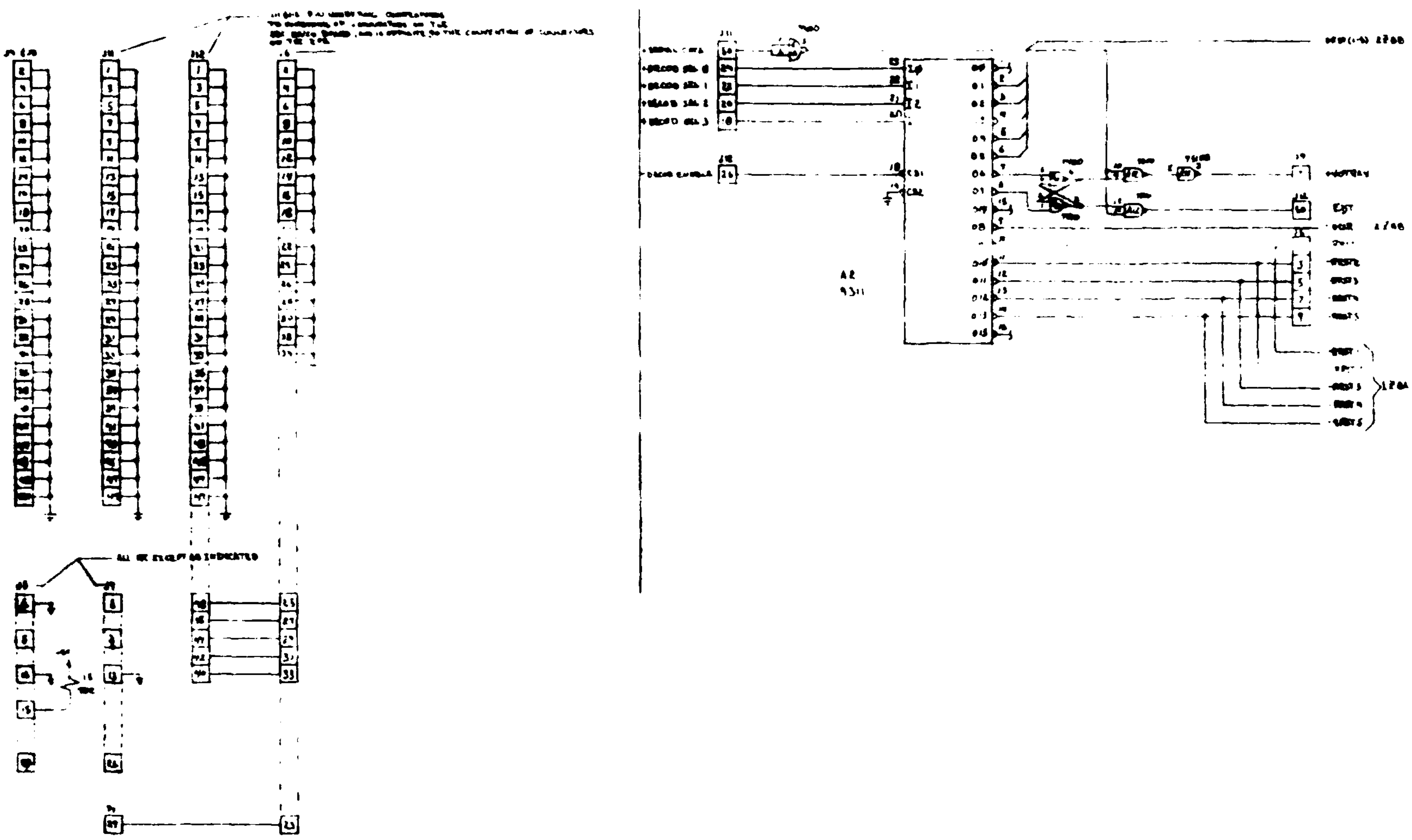


Figure III-19. Interface Board Schematic (3 of 3)

Each of the other four unaffected 8212 chips may also contain data, but are held temporarily in an inactive "three-state" and present a high impedance load to the bus. The only quadrant data available at the main board port 2, therefore, are from the 8212 being serviced. These data are read into memory and the data read signal to the 9311 is removed. This removes the read command to the 8212 and clears its interrupt service request. A pulse is then sent from port 6 to the 9311 which issues a reset signal from the IFB to the rifle electronics associated with the serviced 8212.

The serviced 8212 is now in three state, its service request line is off and it is ready to latch in new data upon receiving the next trigger-pull signal. In the meantime, if other 8212 chips need service as indicated by assertion of the ORED line, the computer polls the next 8212 interrupt line. If it needs service, the process is repeated; if not, the next 8212 service line is polled in sequence. This continues until the ORED service line goes off and the computer moves ahead with the remainder of the program.

A "Target Present" signal from the IR spot projector is carried directly through the interface board to the main board through input port 2. The target present information is recorded and used during scoring to identify a valid target.

b. USART I/O

The control terminal is an electronic data terminal operating at a rate of 300 bits per second, Reference 1. At the initiation of each training session, the computer connects the output serial data stream from the 8251 programmable communication interface or Universal Synchronous/Asynchronous Receiver/Transmitter (USART) to the terminal. The computer, therefore, is able to carry on a two-way conversation with the squad leader in order to obtain "initialization" data as shown on Figure 6. The computer questions the squad leader and prompts for answers by issuing the character ":".

During the actual training session, the USART output is switched to the digitized word audio system. When the session is finished, the squad leader strikes/presses the start/print button on the instructor's console and USART output is again directed to the terminal which types out hard copy scores, as also shown on Figure III-20.

c. UPI-41 MICROCOMPUTER OUTPUT

During a training session, console CRT data are output in parallel from port 6 of the 30/20-4 single board computer to an 8741 Universal Peripheral Interface Slave Microcomputer (UPI-41) on the IFB. The UPI-41 decodes the parallel data and sends a 19,200 BAUD, 7 bit ASCII data stream to the console CRT. The console CRT translates the serial data stream into a score message and displays the message in the column reserved for the appropriate rifle. The UPI-41 also monitors the setting of 5 control switches, one for each rifle which allows the squad leader to inhibit the display of scores for any or all rifles.

```
WANT ID YES OR NO
NO
LET'S START
```

"INITIALIZE" PORTION OF TRAINING SESSION

```
RIFLE:  1

YOUR RESULTS ARE:

TOTAL SHOTS:  99
HITS:  16
MISSES:  29
LOWS:  2
LOW RIGHTS:
RIGHTS:  6
HIGH RIGHTS:  3
HIGHS:  4
HIGH LEFTS:  8
LEFTS:  22
LOW LEFTS:
NO TARGET:  9
TARGETS IGNORED:  8
TARGETS SHOT AT:  30
AVERAGE TIME:  1.2 SECONDS

OH,WELL:  THERE'S HOPE IF YOU SPEED UP
YOUR OVERALL SCORE IS:  37
```

SESSION PROPER.
NO OUTPUT TO TERMINAL . OUTPUT IS VIA VOTRAX DIGITIZED AUDIO WORDS & CONSOLE CRT. THIS PHASE IS TERMINATED BY AN INTERRUPT FROM TERMINAL.

"PRESENTATION OF RESULTS"

Figure III-20. Typical Printout Format on Terminal
(Continues for all 4 rifles)

The UPI-41 system description is divided into four parts: part 1, a functional summary and a component interface description are presented. Performance criteria are also established in this section. Part 2 describes the facilities available within the UPI-41 and explains their use in the present application. Part describes the UPI-41 control program and part 4 evaluates the system with respect to assumption validity, performance criteria, and maximum system capabilities. The source program is given in Appendix D.

d. UPI-41 MICROCOMPUTER OUTPUT II

(1) System Description

The function of the intelligent controller is to receive parallel data from the SBC 80/20, decode the data, and cause a message to appear on the ADM-3A screen based upon the content of the data received. The control switch settings also affect controller operation, but only secondarily.

A block diagram showing the system component relationships appears in Figure III-21.

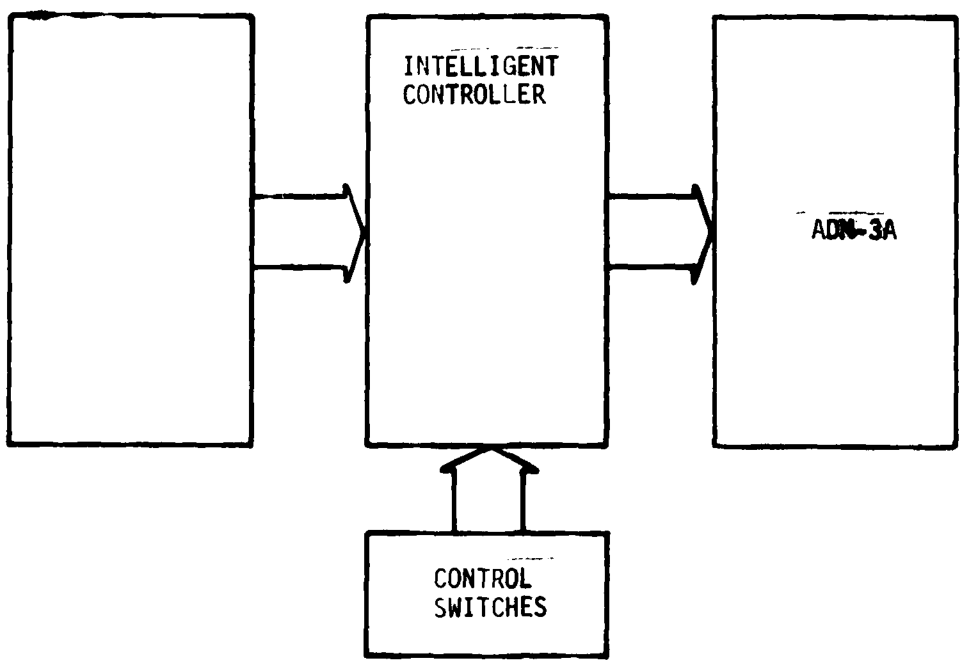


Figure III-21. UPI-41 Intelligent Controller System Block Diagram

The following describes the three component interfaces shown in the figures: SBC 80/20 to controller, controller's to ADM-3A, and control switches to controller.

(a) SBC 80/20 To Controller Interface

The SBC 80/20 to controller interface is comprised of three sets of connections The first set, consisting of 8 data lines and 1 control line, are the data transfer connections. The second set consists of the clock connections while the third set consists of only one connection, the initialization connection.

. Data Transfer Connections

The 8 data lines of the data transfer set connect an 8 bit output port on the SBC 80/20 to the 8 bit Interface Register of the UPI-41. There are six I/O ports on the SBC 80/20 numbered 1 through 6 (1). These ports are divided into the Group A ports, 1-3, and the Group B ports, 4-6. Each port group corresponds to a single 8255 Programmable Peripheral Interface, PPI. Port 4 of Group B is programmed as an output port and used for the SBC 80/20 to UPI-41 data connection.

To transmit data to the UPI-41, the SBC 80/20 places data on port 4 and sends a Data-Available pulse to the UPI-41 over the control line. The Data Available pulse is software generated and is transmitted through port 3 of Group A 8255. The length of the Data Available pulse is set by the time required to execute the instructions necessary to change the logic level of the control line twice, first from high to low, then from low to high. For the SBC 80/20 this results in a 10 microsecond pulse. The maximum pulse length to the UPI-41 is set at twice the instruction cycle length, or 6.5 microseconds; therefore, the 10 microsecond Data Available pulse is sent to the one shot within the controller where it is shortened to 1 microsecond. The 1 microsecond pulse from the one shot supplies the WR input to the UPI-41. On the rising edge of this pulse the data on the SBC 80/20 output port is latched into the UPI-41 Interface Register. SBC 80/20 to controller data transfer connections are illustrated in Figure III-22.

Each byte of data transferred from the SBC 80/20 to the UPI-41 contains two kinds of information encoded into separate fields within the byte. The three most significant bits contain a source identifier encoded in straight binary, and the four least significant bits contain a message identifier, also in straight binary, see Figure III-23. Bit four is not used.

The rate of data transfer from the SBC 80/20 to the controller can be characterized by three separate data transfer rates of which the last two will be of interest. The first two rates are determined by the SBC 80/20 input configuration, Figure III-24, while the third is determined by the input configuration in combination with the SBC 80/20 data processing rate.

The SBC 80/20 input configuration consists of 5 input sources, where each source contains a data latch and a service request line. When data is latched into one of the sources, the SBC 80/20 receives a service request signal from that source. For each service request that the SBC 80/20 responds to, a data byte will be sent to the controller.

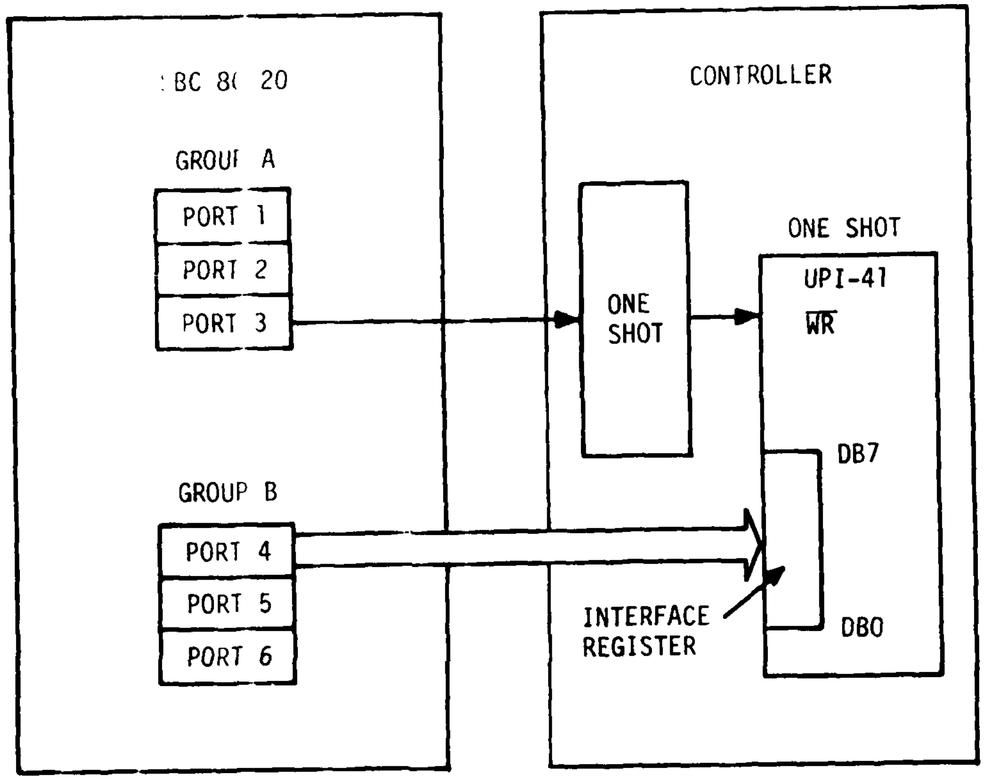


Figure III-22. SBC 80/20 to Controller

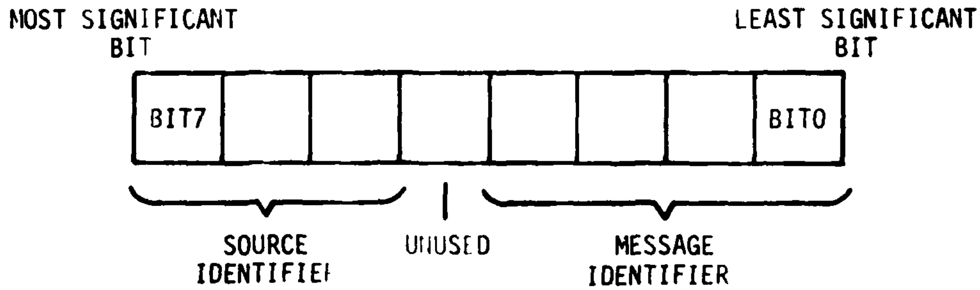


Figure III-23. SBC 80/20 to UPI-41 Data BYTE

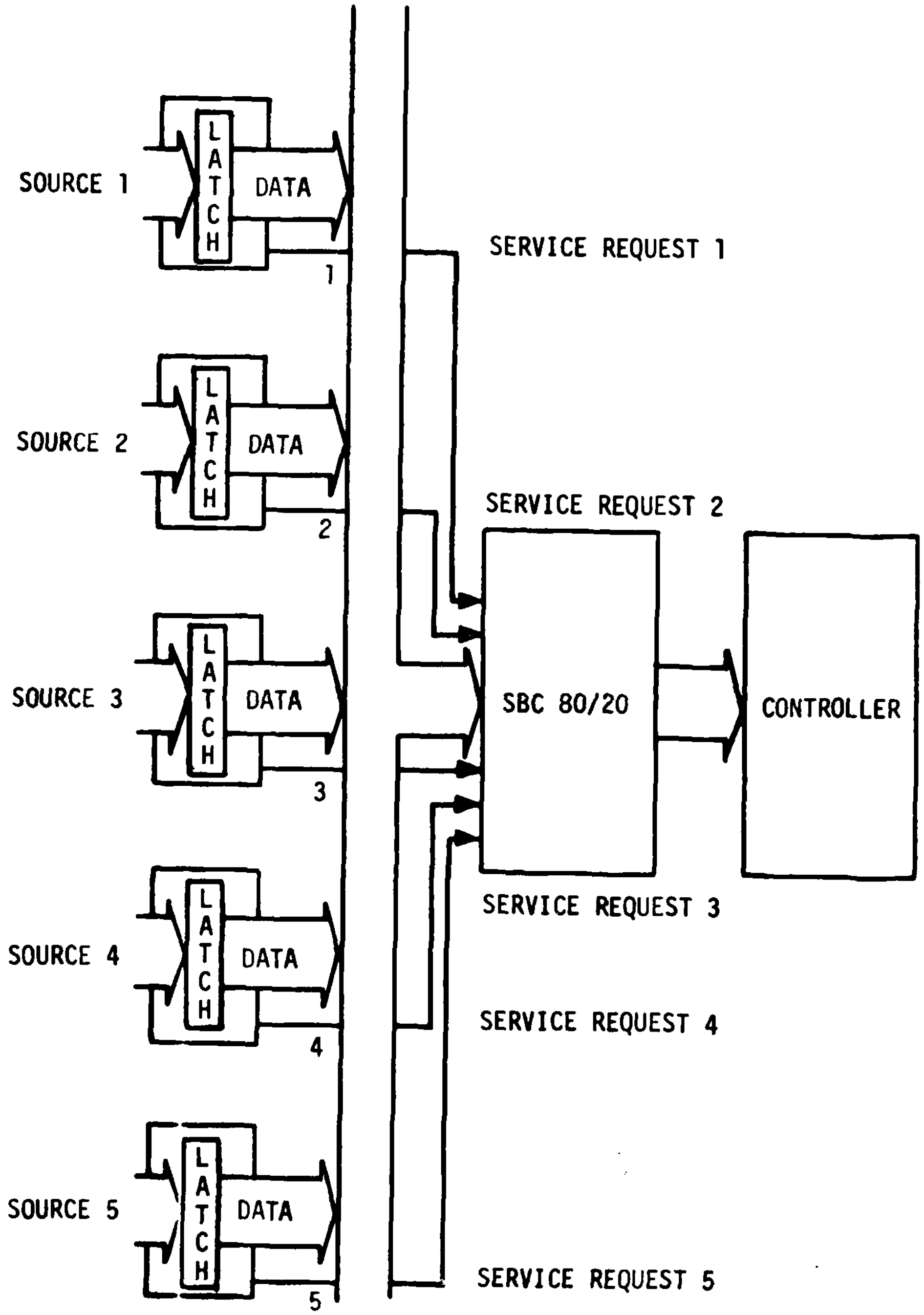


Figure II -24. SBC 80/20 Input Source Configuration

The first data transfer rate is the average transfer rate and occurs when the 5 sources are initiating service requests at their norminal rate. The second data transfer rate is a peak average rate, and occurs when all 5 sources are initiating service requests at their maximum rate of 12 per second. This condition results in a peak average rate of 12 x 5, or 60 transfers per second. The third data transfer rate is the maximum rate, and occurs anytime there are simultaneous service requests to the SBC 80/20. This rate is determined by the processing rate of the SBC 80/20. Analysis using: (1) real-time emulation under control of Intel's In Circuit Emulator, ICE-80, (2) tabulation of instructions executed and their execution time and (3) experimental determination, indicates that the SBC 80/20 processing rate is approximately 200 inputs per second.

As indicated before, the peak average transfer rate of 60 transfers per second, and the maximum transfer rate of 200 transfers per second are the relevant quantities characterizing the data transfer interface.

To keep up with the SBC 80/20 over extended periods, the processing rate of the UPI-41 must equal or exceed the SBC 80/20 peak average transfer rate, and to keep up with the SBC 80/20 when simultaneous service requests have occured, the reception rate of the UPI-41 must equal or exceed the SBC 80/20 maximum transfer rate.

The requirement on the UPI-41 processing rate will be used in the sequel to determine the baud rate used in the controller to ADM-3A interface, while the requirement on the UPI-41 reception rate will be used to establish the necessity of a data queue within the UPI-41.

One final point is that there are no provisions for the UPI-41 to indicate that it is ready to accept a data transfer from the SBC 80/20. Thus, the data queue mentioned above will be filled by an interrupt driven procedure. This technique will assure that a data byte has been removed from the Interface Register before an additional data transfer can occur.

2. Clock Connections

The clock connections supply the UPI-41 clock inputs, X1 and X2. A single line from the SBC 80/20 supplies the controller with a 9.216 megahertz clock which the SBC 80/20 makes available as the BCLK output. Within the controller, the BCLK frequency is divided in half by a 7474D flip flop. This division is necessary to bring the BCLK frequency within the 1 to 6 megahertz operating range of the UPI-41. The Q and $\overline{Q}_0$ outputs of this flip flop supply the UPI-41 inputs, X1 and X2, with a 180° out of phase 4.608 megahertz clock. While the UPI-41 is capable of generating its own clock by connecting a crystal to the X1 and X2 inputs, the BCLK frequency is used since the standard asynchronous communication frequencies can be derived from it. The clock connections are shown in Figure III-25.

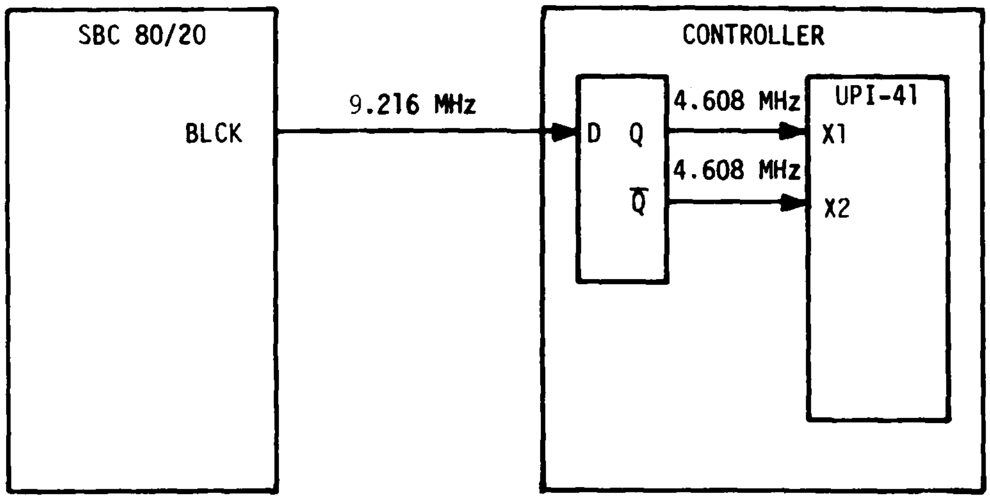


Figure III-25. SBC 80/20 to Controller - Clock Connections

3. Initialization Connection

The initialization connection is between $\overline{\text{INIT}}$ output of the SBC 80/20 and the $\overline{\text{RESET}}$ input of the UPI-41. A low going pulse on this line causes the control program of the UPI-41 to begin execution at location 0.

(b) Controller to ADM-3A Interface

The controller to ADM-3A interface consists of a single line which originates from line 0 to port 1 on the UPI-41, passes through the 75188 inverting line driver, and terminates on the Receive Data, RXD, input of the ADM-3A. The line driver converts the TTL output of port 1, 0 - 5 volts, into RS-232C logic levels of ± 12 volts.

Information is transmitted from the UPI-41 to the ADM-3A serially using 7 bit ASCII code under the RS-232C communication protocol. For this application, the number of bits per character has been minimized by using a single stop bit and no parity bit. For a given serial transmission rate this configuration will result in the fastest possible character transmission time. This time is an important consideration, as each parallel byte received by the controller from the SBC 80/20 will require a 22 character message to be transmitted. With the single start bit, the 9 bit serial character appears as shown in Figure III-26.

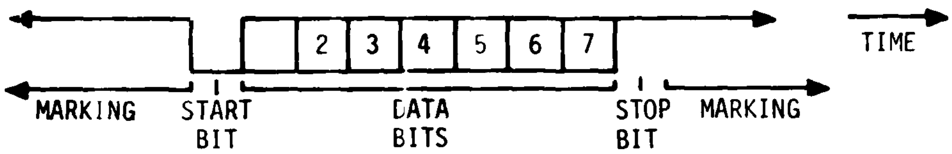


Figure III-26. Serial Transmission Character

Each data byte received by the UPI-41, except as noted in the next section causes a string of 9 bit characters to be sent from the UPI-41 to the ADM-3A, a 24 line by 80 character CRT display.

The function of the ADM-3A is to provide three kinds of information concerning the SBC 80/20 inputs to an observer. The ADM-3A displays a message, indicates the SBC 80/20 source corresponding to the message, and reflects the order of input occurrence. The message is indicated by the characters displayed on the screen. The source is indicated by dividing the ADM-3A screen into 5 columns of equal width, with the first column reserved for source 1 messages, the second column for source 2 messages, and so on for the five sources. The order of inputs is indicated by scrolling the display 1 line each time a message is displayed.

For a screen width of 80 characters, and not allowing an overlap of columns, the message field for each source is limited to the integer portion of 80/5, or 16 characters. The ADM-3A screen use is illustrated in Figure III-27.

To implement the function of the ADM-3A as described above requires that 22 characters be sent to the ADM-3A for each SBC 80/20 to controller transfer. The 22 characters are sent in 3 groups: a cursor control group, a message group, and a display control group.

The first group sent, the cursor control group, contains four characters which cause the cursor to the ADM-3A to position itself at the beginning of one of the five message columns. The first two control characters "escape" and 'equals", activate the ADM-3A cursor positioning logic, while the next two characters are interpreted as the X and Y coordinates of the new cursor position, respectively. The Y coordinate sent is always the same, 037H, and selects the bottom line of the display. The X coordinate is determined by the SBC 80/20 input source.

The second group sent, the message group, contains 16 characters. These characters will be printed on the screen of the ADM-3A in the message field whose beginning was established by the cursor positioning control group.

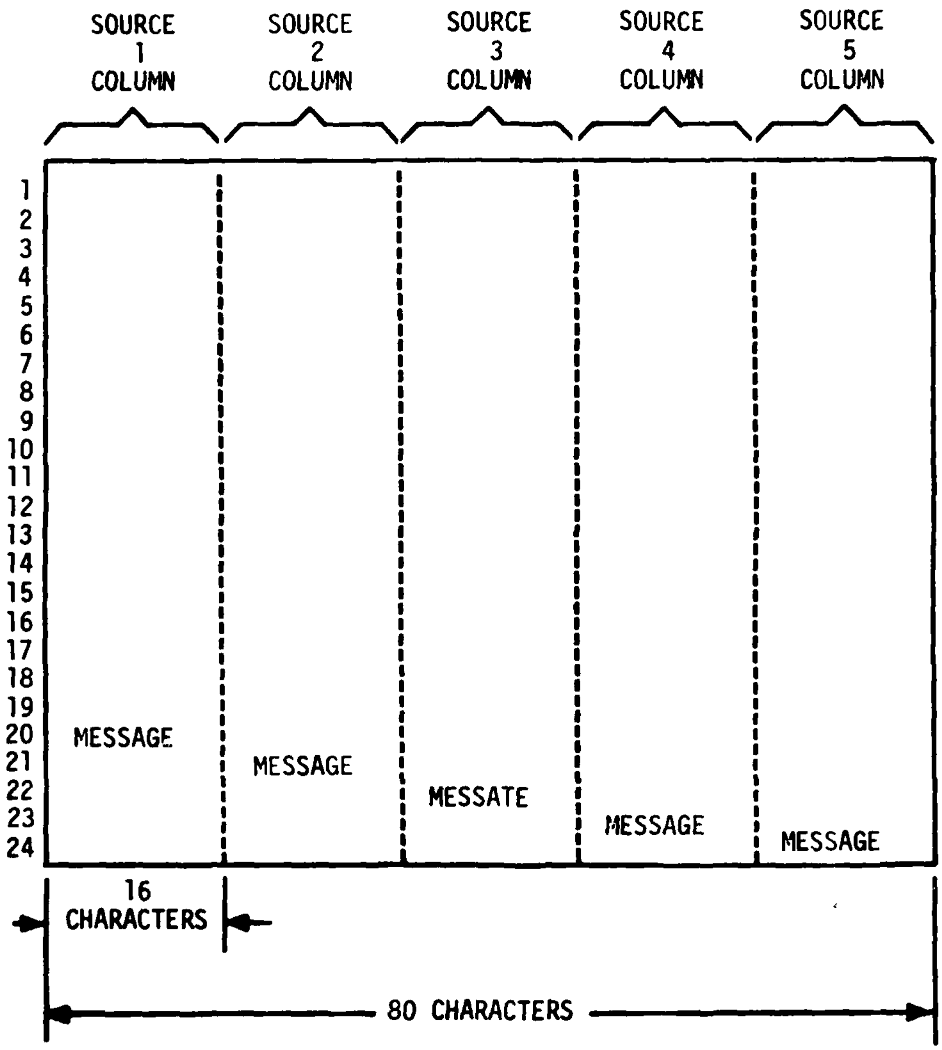


Figure III-27. ADM-3 Screen Use

The third group sent, the display control group, contains the remaining 2 characters. These characters, a carriage return and line feed, cause the display to scroll up one line in preparation for the next control group 1 sequence.

The complete 22 characters string appears as shown in Figure III-28.

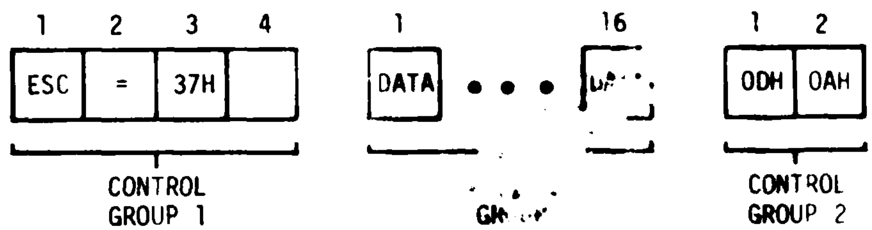


Figure III-28. Character String Transmitted to ADM-3A

The final aspect of the controller to ADM-3A interface is the serial transmission rate to be used. Having now established (1) the number of characters sent by the controller to the ADM-3A per SBC 80/20 input, (2) the number of serial bits per character, 9, and (3) the UPI-41 processing rate requirement, 60 transfer /sec, a minimum serial transmission, or baud, rate can be computed as:

$$\text{minimum baud rate} = \begin{array}{l} 22 \text{ characters/SBC 80/20 transfer x} \\ 9 \text{ bits/character x} \\ 60 \text{ SBC 80/20 transfers/second} \end{array} \qquad (1)$$

or 11,880 bits per second. The next highest, indeed the highest, baud rate at which the ADM-3A can receive data is 19,200 baud. This value must necessarily be chosen as the data transmission rate.

(c) Control Switches to Controller Interface

The control switches to controller interface is a 5 line connection between 5 control switch outputs and the 5 least significant inputs of port 2 on the UPI-41. The design of port 2 on the UPI-41 is such that if nothing is connected to a port line, the line will read as a logic one, whereas, if the line is grounded through a 1k resistor, the port will read a logic zero (3). The control switch to controller connections are shown in Figure III-29.

During the processing of a data byte by the UPI-41, the binary source identifier is translated into a linear select code which is then compared with the switch setting on port 2. If the switch corresponding to the source identifier is set in the abort position, a logic 0 is present and a message will not be sent. This is the exception referred to in the controller to ADM-3A interface description. If the switch is set in the display position

a logic true will be present and a message will be sent.

This concludes the overall system description. The next two sections will describe the principle device within the intelligent controller, the UPI-41 single chip microcomputer.

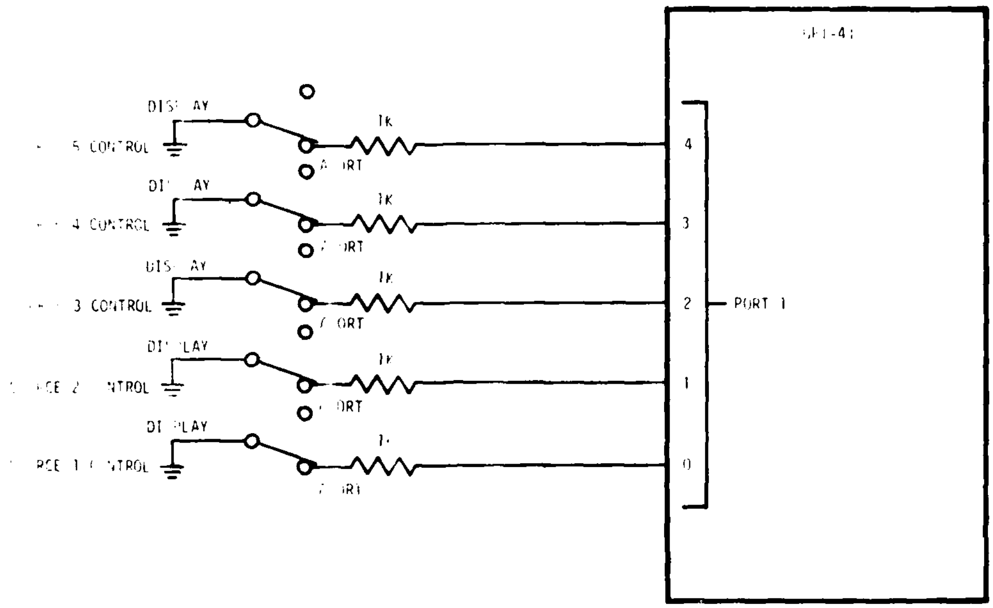


Figure III-29. Control Switches to Controller Interface

e. UPI-41 MICROCOMPUTER OUTPUT II

The UPI-41 single chip microcomputer provides the intelligence of the intelligent controller. The block diagram in Figure III-30 illustrates the facilities available within the UPI-41.

As described in the previous section, the interface register is used for communication with the SBC 80/20, port 1 is used for communication with the ADM-3A, and port 2 is used for communication with the control switches.

Program memory is divided into 4 pages of 256 bytes each. These pages are numbered 0 to 3. Page 0 contains the main loop of the control program, while page 1 contains the various subroutines called by the main loop. Page 3 has a special feature in that data bytes can be transferred from it to the accumulator using the current value of the accumulator as a pointer. This "table lookup" feature is used to access the message strings which are sent to the ADM-3A. 16 messages of 16 characters each are stored, using all 256 bytes within the page. Program memory configuration is shown in Figure III-31.

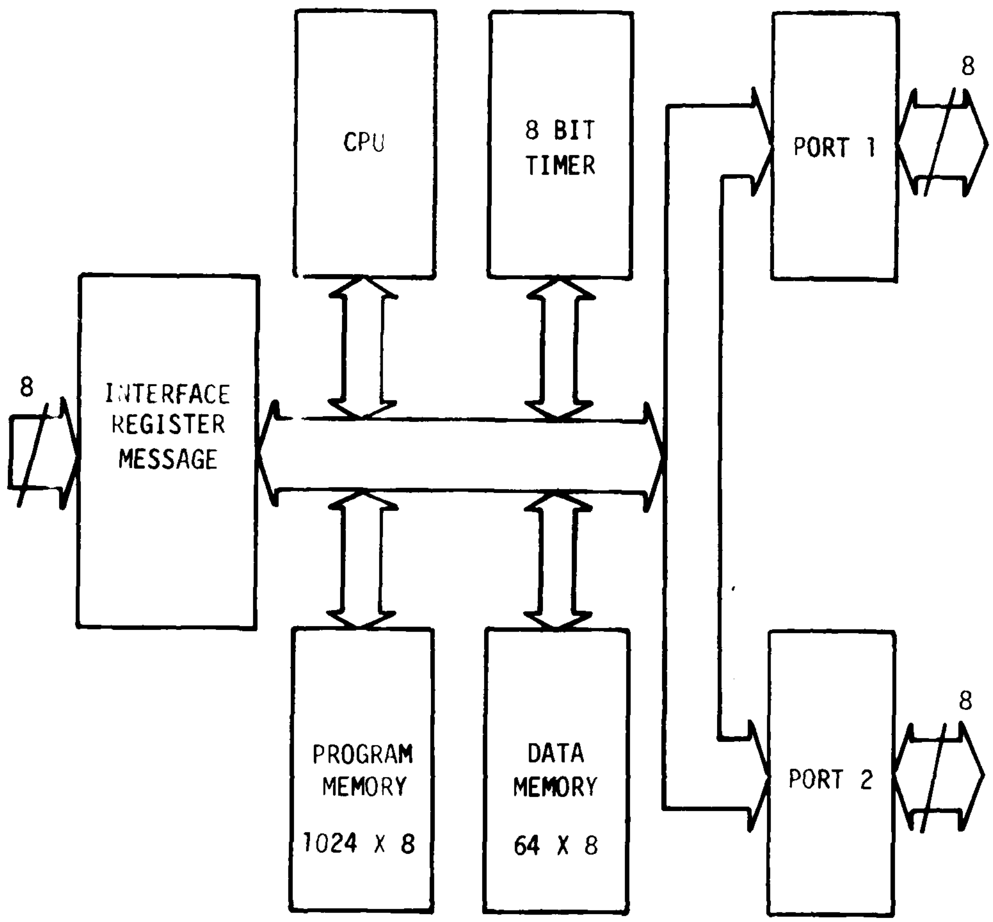


Figure III-30. UPI-41 Single Chip Microcomputer Block Diagram

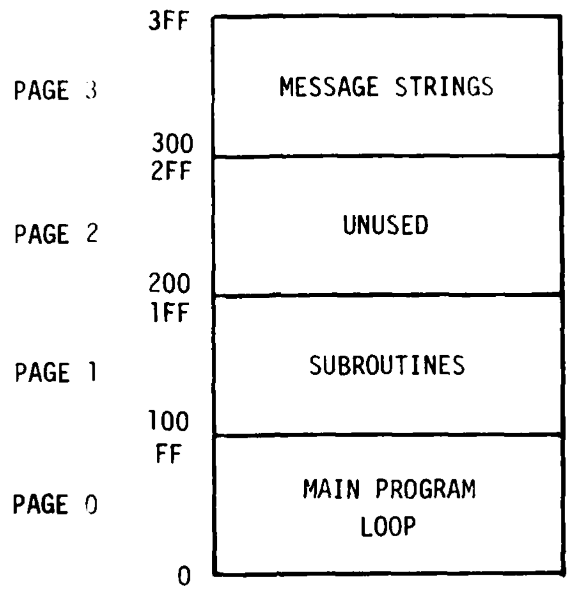


Figure III-31 UPI-41 Control Program Memory Map

RAM within the UPI-41 serves three purposes: it contains the registers, the subroutine and interrupt stack, and the variable data storage locations. The distribution of the 64 RAM locations between these three functions is shown in Figure III-32.

The registers in bank 0 are designated R0-R7, while those in bank 1 are designated R0'-R7'. Only one register bank at a time can be addressed. Bank selection is accomplished by executing a specail select register bank X, SELRBX, instruction where X is either 0 or 1. The registers of bank 0 are used for data processing and message transmission, while those of bank 1 are used for queue control.

The UPI-41 contains a rather sophisticated timer which was evaluated for use as the bit interval generator for UPI-41 to ADM-3A serial transmission. As several difficulties were encountered, the use of the timer while representing a possible area for future research, was rejected in favor of a software timing approach. The software timing routine will be described, along with the rest of the UPI-41 control program, in the next section.

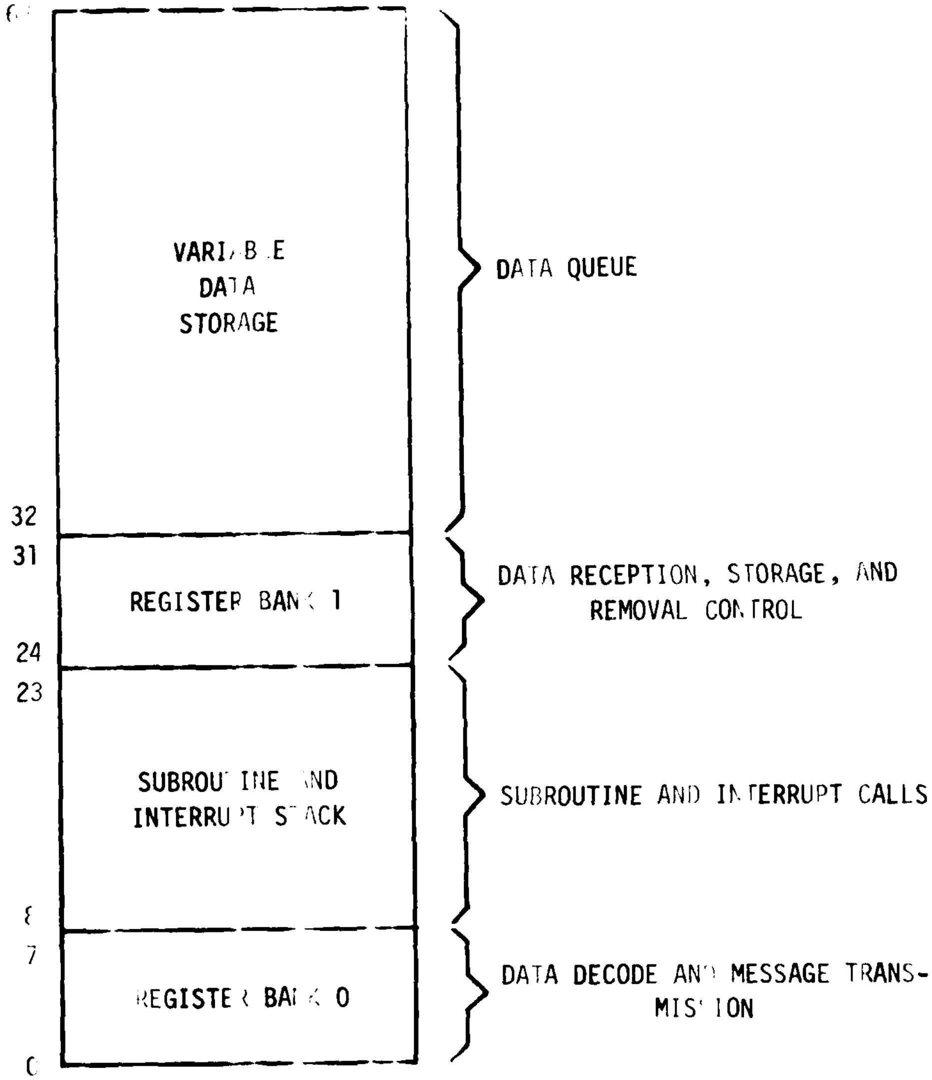


Figure II-32. UPI-41 RAM Memory Map

f. UPI-41 CONTROL PROGRAM IV

The UPI-41 program is written in MCS-48/UPI-41 assembly language. It was assembled using a cross assembler operating on an Intel Microcomputer Development System, MDS-800. The machine code was burned into the EPROM program memory of the UPI-41 using an Intel Universal Prom Programmer and the Universal Prom Mapper Software. The assembly of the program and the burning of the EPROM were done under control of the Intel System Implementation Supervisor, ISIS II, operating from an Intel Dual Floppy Disk Drive.

The program description is divided into three parts:

- Initialization procedures
- Data reception and storage
- Data decode and message transmission

The program listing is located in Appendix "D", flowcharts appear in Figures III-33 through III-35.

(1) Initialization Procedures

The first section of the UPI-41 program performs functions which are necessary prior to data reception. These functions are the initialization of registers and the initialization of the ADM-3A screen. The values placed in the various registers will be explained as they are encountered within the program. The screen initialization procedure consists of clearing the screen and positioning the cursor in the bottom left hand corner. The screen is cleared by transmitting a special character, 01AH, to the ADM-3A, while the cursor is positioned using the 4 character cursor positioning sequence described previously in the controller to ADM-3A interface section.

As the final step in the initialization procedures, the UPI-41 enables itself to data reception by outputting a logic zero to port 2 line 7. This port line is connected to the UPI-41 chip select, $\overline{CS}$, input. Since all port lines are in the logic high state following a system reset, UPI-41 input is disabled until the output instruction is executed.

(2) Data Reception and Storage

When data is written into the UPI-41 interface register by the SBC 80/20, an interrupt request is generated. Upon recognition of the interrupt, the interrupt vector jump at locations 3 and 4 in program memory is executed, and the interrupt service routine, lines 118 through 134 in Appendix "D", is entered. The interrupt routine inputs the data from the interface register and places the data in a queue. A flowchart of the interrupt service routine appears in Figure III-34.

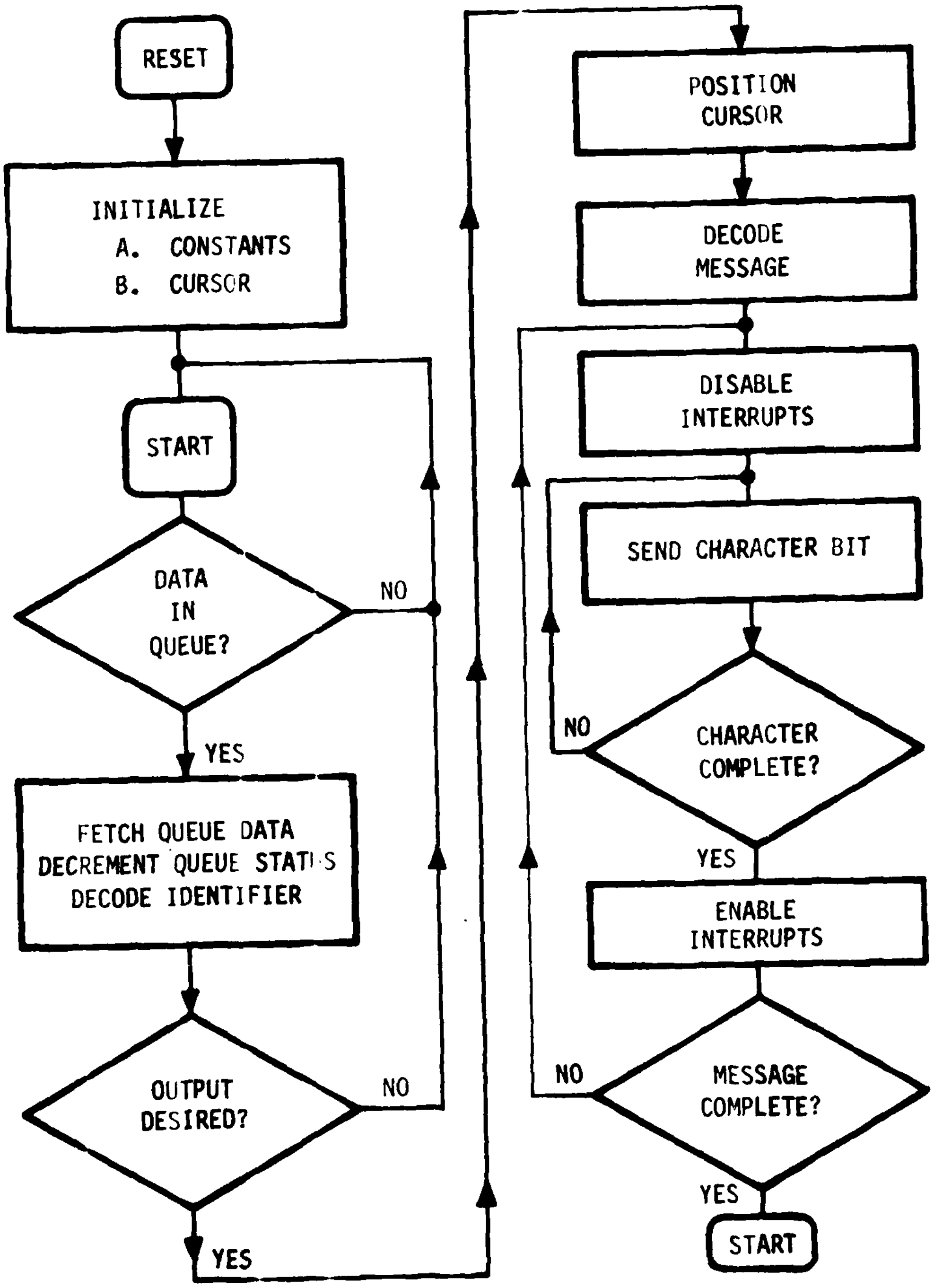


Figure III-33. UPI-41 Control Program Flowchart Processing Loop

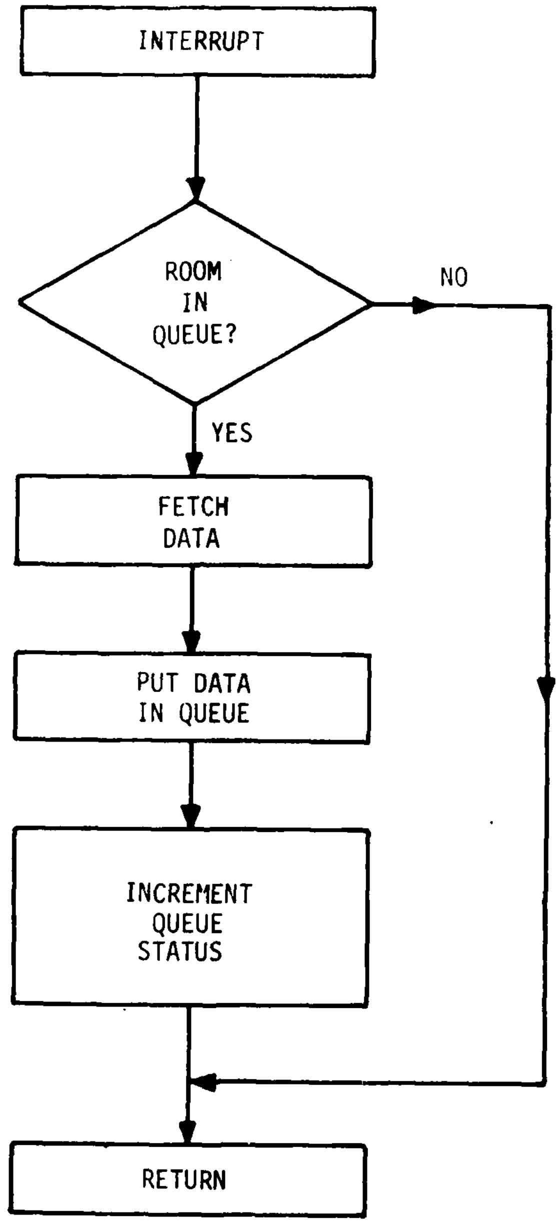


Figure III-34. UPI-41 Control Program Flowchart - Interrupt Service Routine

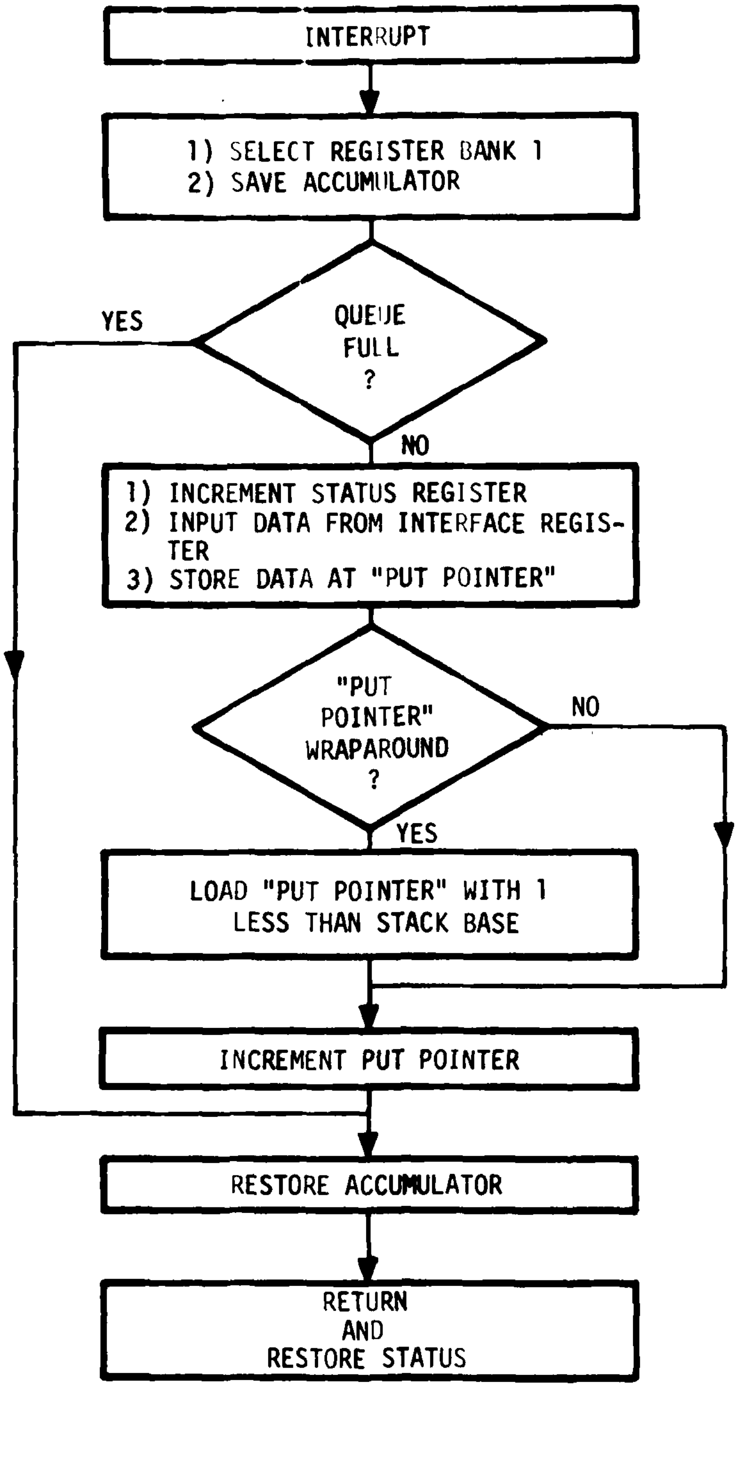


Figure III-35. Interrupt Routine Flowchart

It was pointed out in the section describing the SBC 80/20 controller interface that the UPI-41 reception rate requirement would necessitate the data queue. The necessity for the queue can be shown as follows:

Unless the 19,200 baud rate can meet the UPI-41 reception rate requirement as well as the processing rate requirement, it is necessary to provide a data queue to prevent data from being overwritten in the interface register. For this condition to be met, the 19,200 baud rate must be proportionately greater than the 11,800 minimum baud rate by at least the proportion of the reception rate requirement to the processing rate requirement, or

$$\frac{19,200}{11,800} \overset{M}{=} \frac{200}{60} \qquad (2)$$

as this is not true, a queue must be maintained.

To meet the storage requirements a First In First Out, or FIFO, stack is implemented in the variable data storage area of the RAM memory. See Figure III-36. A FIFO stack allows data to be retrieved so that order of entry is preserved. The operation of a FIFO stack can be conceptualized by considering a storage mechanism where data inputs are stacked one on top of the other as they arrive, and where data removal is accomplished by pulling from the bottom. As an entry is removed, all remaining entries move down one location. This operation is illustrated in Figure III-36.

The problem with this implementation is in moving the remaining data entries down. For N remaining inputs, the operation requires 2N memory accesses and 5N program steps as shown below:

(a) Increment pointer

(b) Load data byte - first memory access

(c) Decrement pointer

(d) Store data byte - second memory access

(e) Increment pointer

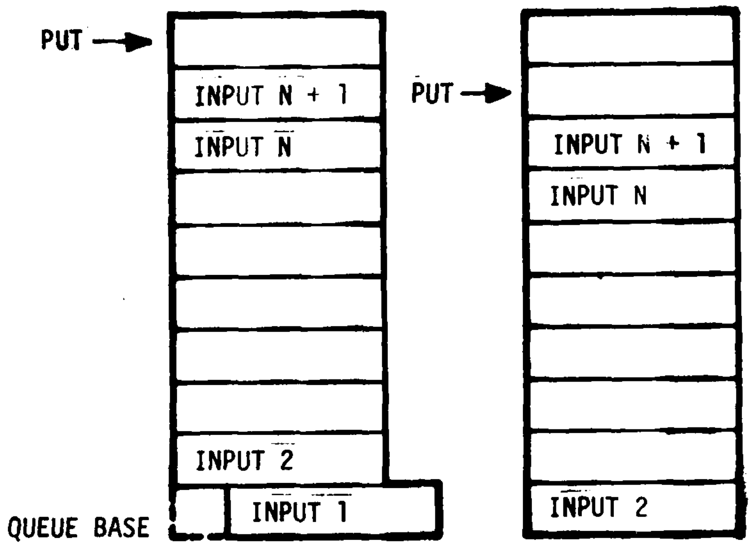


Figure III-36. Fixed Base FIFO Operation

A more efficient algorithm uses a "get data" pointer as well as the "put data" pointer used in the implementation above. The get data pointer allows the "bottom" of the stack to move upward as data is removed from the stack. This eliminates the necessity of moving each of the remaining inputs down. Instead, the get data pointer is incremented once each time data is removed. The put data pointer always identifies the next location available for data storage and the get data pointer identifies the location of the next value to be removed. The only problem with this implementation is that unless data memory is infinitely long, storage locations will run out at some point. This condition being unacceptable, a "top-of-stack" must be defined, and as the pointers reach the top they must be wraparound. In this application the top-of-stack has been made coincident with the top of RAM, making the last location address 63 and giving a stack size of (63-32) +1, or 32 locations. As each pointer reaches location 63, it is returned to location 32 instead of being incremented further. Implemented in this manner, the number of steps required for a data removal is independent of N and, for the UPI-41, has a maximum value of 5 as indicated by lines 85 through 89 of the program listing.

For either implementation, some way of determining when the stack is full must be available. For the two pointer implementation, the queue full condition is easily detected by maintaining a queue status value which indicates how many entries are presently on the stack. If a check of the queue status register indicates that the queue is full, additional data must be rejected to avoid overwriting of the earliest entry with the newest entry. Since the UPI-41 has been designed to meet the processing rate requirement, it follows that the maximum stack usage must be less than or equal to the number of SBC 80/20 input sources, or 5; therefore, the queue full condition can never occur in this application. Use of the queue status value in this application, then, is limited to determining when data is available on the stack. Figure III-37 illustrates the operation of the moving base FIFO stack.

The put and get data pointers, the queue status, and the constants used to determine the pointer wraparound and queue full conditions are located in register bank 1. Also, since the data reception routine is entered in response to an interrupt, another bank 1 register is allocated for accumulator storage. Finally, one register is used for temporary data byte storage during computations.

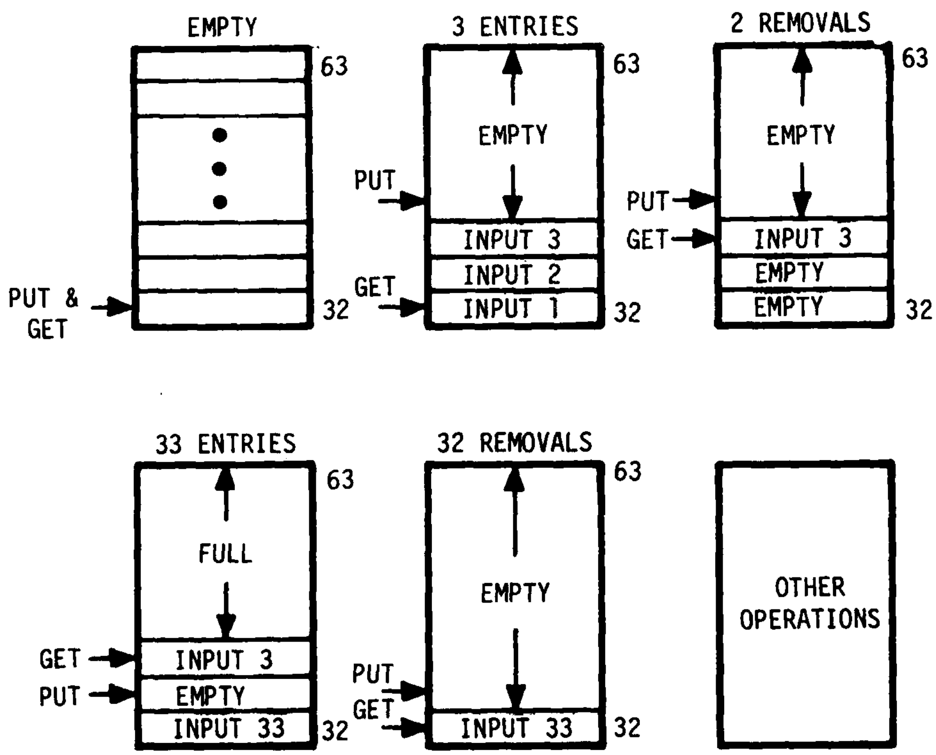


Figure III-37. Moving Base FIFO Operation

Registers 0 and 1 are the only locations which can serve as pointers into the variable data storage area; therefore, the get and put data pointers are defined as the contents of registers 0 and 1 respectively, the other locations are assigned arbitrarily as per Table III-1.

TABLE III-1. REGISTER BANK 1 MAP

Register 7'	Temporary Storage
Register 6'	Queue Status Con. = 224
Register 5'	Wraparound Constant = 193
Register 4'	Unused
Register 3'	Accumulator Storage
Register 2'	Queue Status
Register 1'	Put Data Pointer
Register 0'	Get Data Pointer

(3) Data Decode and Message Transmission

Once data is placed in the queue by the interrupt service routine, a check of the queue status register, lines 80 and 81 of the program listing, will indicate that data is available for processing. The program will then enter the main program loop, line 82, where the data decode and message transmission function begins.

This section of the program can be divided into 3 segments:

(a) Data access

(b) Source processing

(c) Message processing

1. Data Access

The function of the data access segment is to remove a data byte from the queue and perform the transition between register bank 1 operation and register bank 0 operation. The data removal steps are reminiscent of the steps performed in the interrupt routine, while the bank transition is accomplished by placing the data in the accumulator and then selecting the new register bank. A flowchart is shown in Figure III-38.

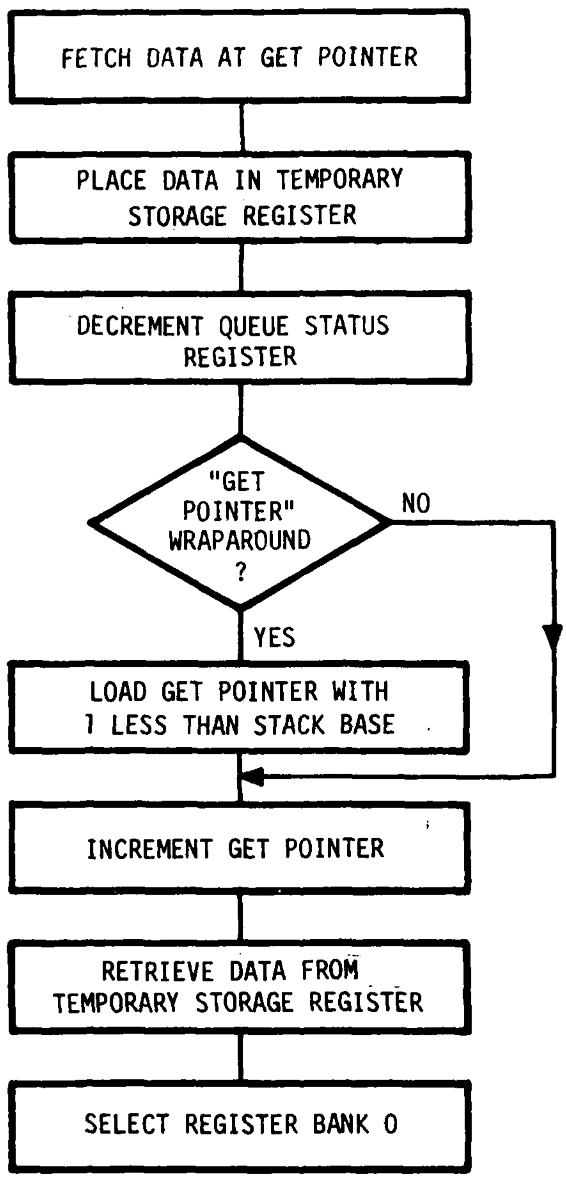


Figure III-38. Data Access Segment Flowchart

Register bank 0 is used for the remainder of the program. All locations within this bank are assigned arbitrarily as shown in Table II -2.

TABLE III-2. REGISTER 0 MAP

Register 7	Data Byte
Register 6	Message Length Constant
Register 5	Binary Source Identifier
Register 4	Linear Select Source Identifier
Register 3	Message Identifier
Register 2	Relay Counter
Register 1	Unused
Register 0	Serial Transmission Counter

2. Source Processing

The function of the source processing segment, lines 93 through 98, is to use the source identifier portion of the data byte to (1) determine whether a message tranmission is desired and (2) position the cursor at the proper place on the ADM-3A screen. The source processing segment calls three subroutines; MASK, LOCSET, and TAB.

Subroutine MASK, lines 144 through 156, coverts the binary source identifier into the linear select identifier through the use of the lookup table located at MSKDAT, line 143. The subroutine then performs the comparison with the port 2 control switch lines and sets a flag according to the result.

Subroutine LOCSET, lines 161 through 168, sends the characters which activate the cursor control logic and the Y coordinate value to the ADM-3A.

Subroutine TAB, lines 157 through 160, converts the binary source identifier into the proper X coordinate value and completes the cursor positioning sequence by transmitting the coordinate value to the ADM-3A.

3. Message Processing

The function of the message processing segment, lines 99 through 112, is to convert the message identifier portion of the data byte into the page 3 address of the message string, output the message string, scroll the ADM-3A display one line, and return to the queue status checking loop.

The page 3 address of the message string is produced by multiplying the binary message identifier by 16. Thus, the message identifier is converted into the starting address of a 16 character string which makes up the message. The multiplication is accomplished by swapping the high and low order nybbles of the data byte and then masking out the low order nybble. This operation is equivalent to four left shifts and, therefore, multiplies the source identifier by 2^4, or 16.

Subroutine STROUT, lines 169 through 175, uses the message address produced by the preceeding multiplication and the string length constant contained in register 6 to control the transmission of the 16 character message string to the ADM-3A.

The CRLF procedure, lines 107 through 110, cause the scroll of the ADM-3A display by sending the carriage return line feed combination.

Finally, register bank 1 is selected so that when the jump at line 112 occurs the register bank containing the queue status value, R2', will be addressed by the WAIT loop.

This completes the description of the control program except for the subroutine which controls character transmission. This function is accomplished by the OUTPUT subroutine, lines 176 through 191.

It was noted in the description of the clock connection, section II, that the 4.608 megahertz clock input to the UPI-41 would be used to generate the proper communication frequency. The following discussion explains this process and the operation of the OUPUT subroutine,

Each instruction in the UPI-41 instruction set consists of either 1 or 2 instruction cycles. Each instruction cycle consists of 5 machine states and each state consisits of 3 clock periods. See Figure III-39.

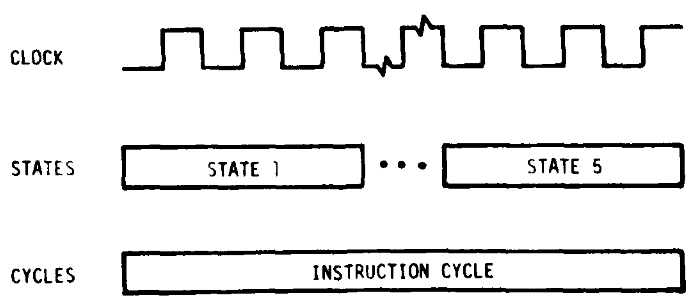


Figure III-39. UPI-41 Instruction Cycle

The instruction cycle execution rate, then, is 1/15 of the input clock rate or 307,200 instruction cycles per second. The instruction cycle execution rate divided by 16 produces the serial transmission rate of 19,200 baud. Therefore, a bit interval, i.e., the time a serial bit should be present on port 1 during transmission, is exactly 16 instruction cycles. A 9 bit character can be transmitted by constructing a loop which places a new serial bit on the port 1 transmission line every 16 instruction cycles.

The OUTPUT subroutine, Figure III-40, expects the 7 least significant accumulator bits to hold the 7 bit ASCII representation of the character to be sent. As 9 bits are required to send a complete character, including the start and stop bits, the 8 bit accumulator and the carry bit are catenated to form a 9 bit register. The accumulators most significant bit and the carry bit serve as the stop and start bits respectively. Once the 9 bit register is set up with the character, the bits are sent by successively rotating the bits into the least significant bit position of the accumulator and then outputting the accumulator to port 1.

Instructions 1, 2, and 3 set up the character, the transmission loop begins at line 180. Note that the number of instruction cycles required for each instruction in the transmission loop is shown to the right of the instructions.

For the first eight bits transmitted, program execution proceeds through the steps indicated 1 through 8. As can be verified by the reader, 16 instruction cycles are executed between bit changes.

```
OUTPUT: DIS     I
        MOV     R0,#07H ;SERIAL BIT COUNTER
        MOV     A,R1    ;GET ASCII CHARACTER TO BE OUTPUT
        ANL     P1,#00H ;PUT OUT START BIT
        MOV     R2,#04H ;SET UP DELAY LOOP LENGTH
        CALL    DELAY
LOOP1:  OUTL    P1,A    ;OUTPUT CURRENT BIT OF SERIAL CODE
        RR      A       ;GET NEXT BIT OF ASCII CODE
        NOP             ;WAIT 1 INSTRUCTION CYCLE TO COMPENSATE
                        ;FOR RR BEING A SINGLE CYCLE OPERATION
        MOV     R2,#02H ;SET UP DELAY LOOP LENGTH
        CALL    DELAY
        DJNZ    R0,LOOP1        ;TEST FOR 7 BITS OUTPUT
        ORL     P1,#01H ;PUT OUT STOP BIT
        MOV     R2,#03H ;SET UP DELAY LOOP LENGTH
        CALL    DELAY
        JF0     NOINEN  ;IF IN SETUP SEGMENT DONT ENABLE INTERRUPTS
        EN      I
NOINEN: RET             ;RETURN FROM SUBROUTINE
```

Figure III-40. UPI-41 Character Transmission Subroutine

Program flow for the final bit proceeds through the steps indicated A through E. While this sequence requires only 9 instruction cycles, analysis of the complete program shows that for any set of conditions a minimum of 8 additional instruction cycles will be required to reach the initial ouput instruction for a new character. Thus, a minimum of 9 + 8, or 17, cycles will be executed exceeding the minimum of 16 by 1 cycle. But, as there is no maximum length for the stop bit since its level corresponds to the nonactive, or "marking" state, the value 17 is acceptable.

The instruction executed just prior to entry into the bit transmission loop diables interrupts, while the instruction just before the return reenables them. Interrupts must be disabled during transmission of a character since the occurance of an interrupt service routine would insert extra instruction cycles, thereby destroying the integrity of the software timing loop.

As a concluding remark on the UPI-41 control program, it is noted that starting on page 51 of the listing, a sample set of message strings is shown.

The program listing referred to throughout this section is the assembly listing produced during the assembly of the UPI-41 control program source file. This version of the program was used for the system evaluation to be presented in the next section.

3. 80/80 PROGRAM

Operation of the 80/20-4 Microcomputer is directed by program code in three 2716 2KX8 EPROMS. The code was compiled from a program written in PL/M-80 language. Reference 3 gives a number of PL/M-80 examples. While reference 5 provides the language syntax and other definitions.

The overall program strategy is shown on Figure III-41, with more detail given on Figure III-42. The program listing is given in Appendix A.

After power has been turned on, the program starts when the 80/20-4 "RESET" button is pushed.

During "initialize" the program issues a series of questions to the system console and prompts for answers as shown on Figure III-41. If desired, the date, training session number, and trainee names are obtained and stored for future reference. When all identification data have been collected and other housekeeping details completed, the program issues "LET'S START" and the main training session loop is entered. This loop may be executed along the three different paths indicated on the flowchart, Figure III-42.

If there is no target present on the screen and no rifle trigger is pulled, i.e., no "action", then path 3 will be selected by program logic. No data comments are generated during early passes around the path 3 loop. Subsequent "action" will cause flags to be set and a return to path 3 may result in a comment of either "NO TARGET" or "YOU FROZE" being sent to the earphones of any erring trainee. Corresponding error data are filled in RAM memory for the identified trainee which will lower his score printed out after the session ends.

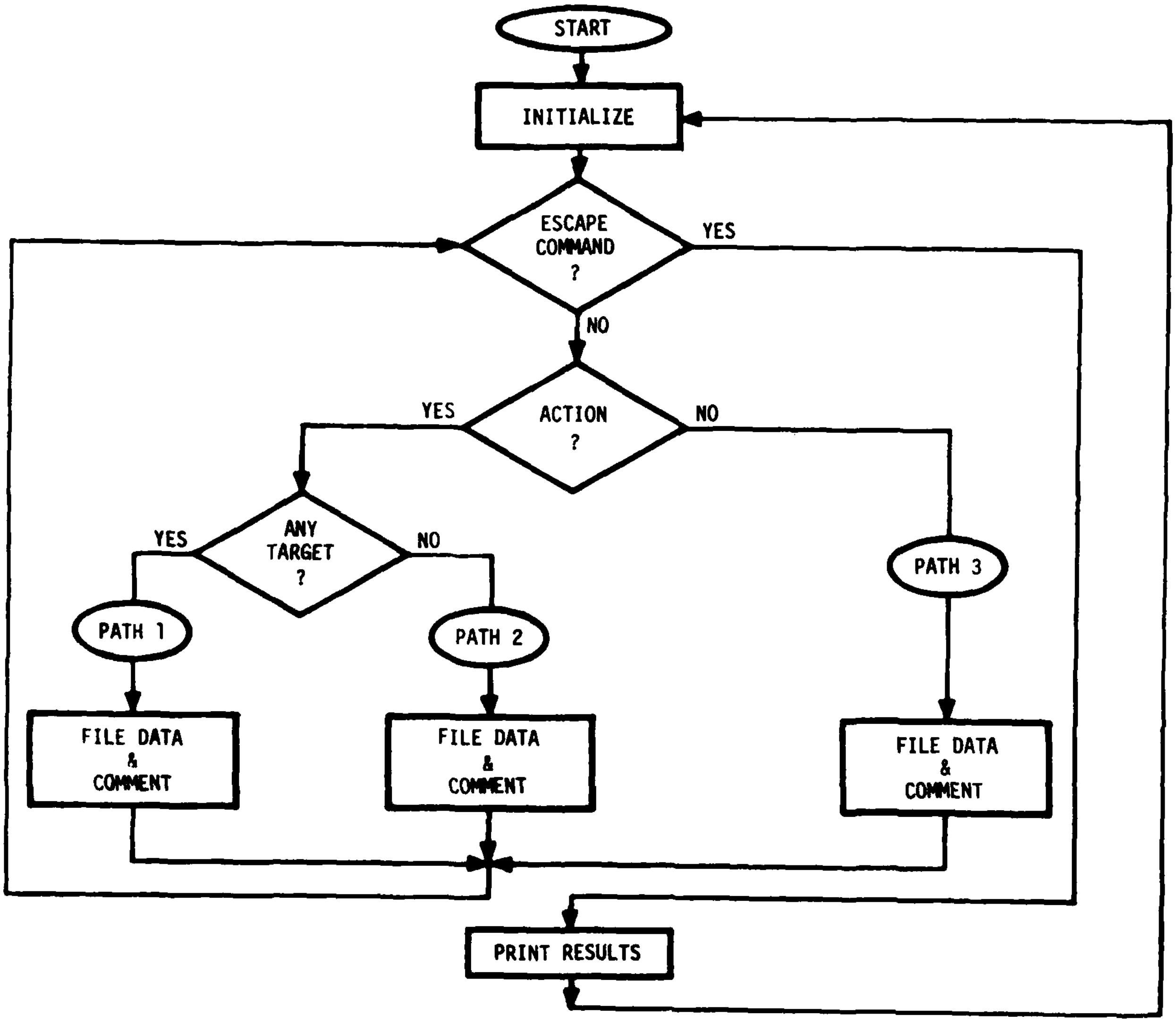


Figure III-41. 8080 Program Strategy

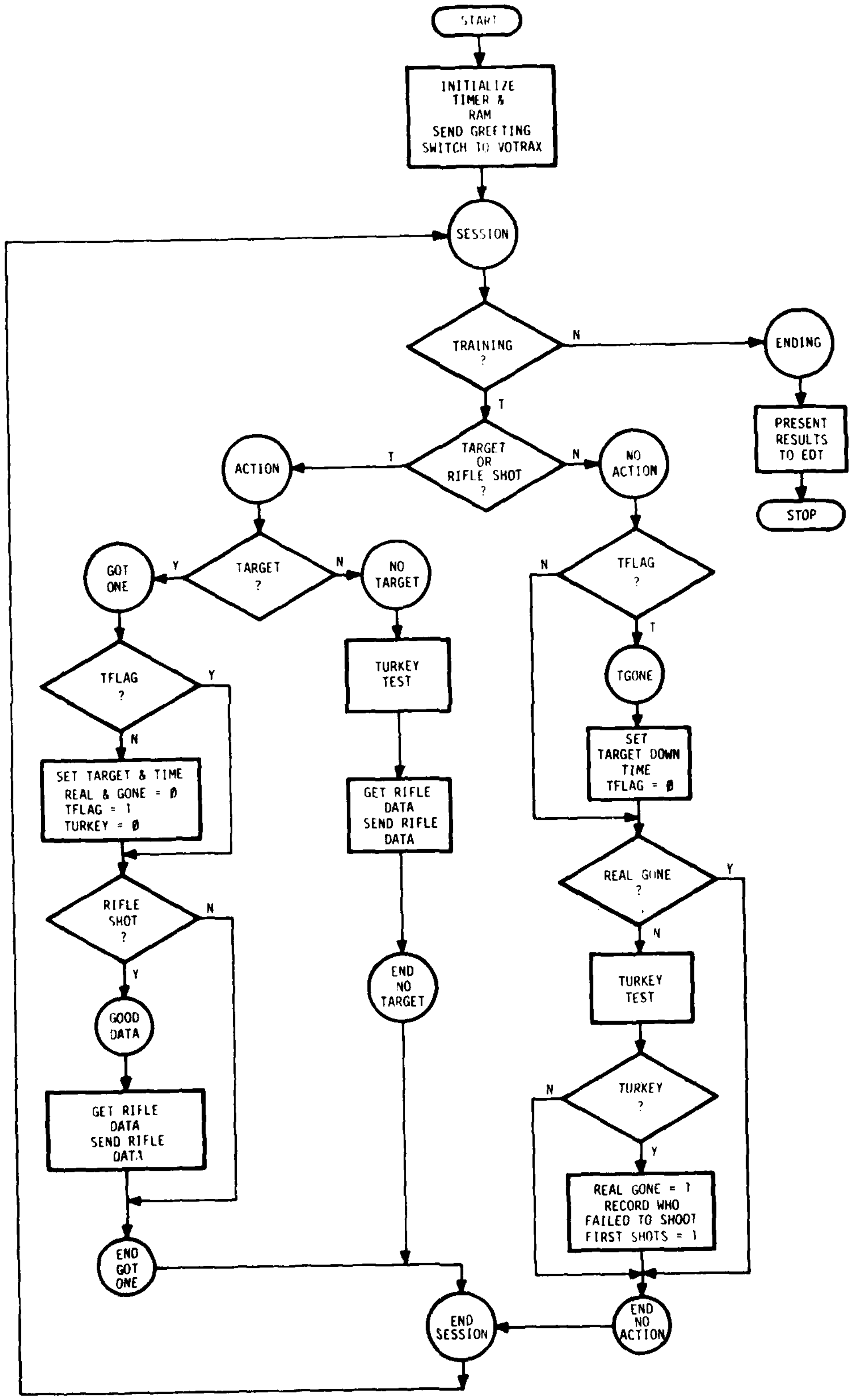


Figure III-42. Program Flowchart

"ACTION" is true after a target becomes available and/or a rifle is "FIRED". The session loop will now pass through either path 1 or 2 as dictated by program logic. This logic also determines the proper data to be filed and comment to be sent to the trainee's earphones. For example, if the target disappears but the trainee persists in shooting for more than one second, then a "NO TARGET" comment will be sent to the rifleman, and a negative score is placed in his data file.

Operation remains locked in the session loop until an escape is signaled by the squad leader's pushing the start/print button. This causes a system interrupt and control passes to "PRINT RESULTS" which produces output as shown on Figure III-41. The program then returns to the "INITIALIZE" block and data records are initialized in preparation for the next training session.

4. SCORE DISPLAY AND WORST PERFORMANCE

The final score for each trainee is calculated by adding the following items:

100 x (Hits per shot)
60 x (Near misses per shot)

30 if average reaction time = 0.5 seconds, or

20 if average reaction time 0.5 but = 0.9 seconds, or
10 if average reaction time 0.9 but = 1.3 seconds, or
0 if average reaction time 1.3 seconds.

-2 x (Number of targets ignored)

When the light emitting diode or "LED" is lit under a trainee's CRT column, he is the "WORST SHOOTER" inasmuch as he has the highest total of these items:

- Misses
- Shots with no target present
- Targets ignored - PP the worst shooter is recomputed each time a traget is not present on the screen.

5. SELF CHECK

The UIWT self check has two parts: (1) an SBC 80/20 check, and (2) the interface board (IFB) check. These procedures are described separately.

a. SBC 80/20 CHECK

The 80/20 single board computer checkout requires the insertion of an INTEL SBC 416 ROM extender board on which is located the test program driver and a duplicate of the UIWT version 1.2 program. The duplicate program is contained in five 2708 ROMS. These ROMS are located at addresses through ØCØØØH, see Appendix C.

The 80/20 check verifies proper operation of the SBC memory, I/O ports, timer and USART. A complete check requires about a second. To run the check, the normal 50 pin connectors to "J1" and "J2" of the 80/20 must be removed and replaced with a special test strap which connects input terminals of J1 to output terminals on J2 and vice versa The SBC 416 board must also be inserted into the computer card cage. While not necessary, it may be convenient to remove the interface board to avoid damage to the wire-wrap pins. The UIWT program is started with a reset in the normal way. The first thing that the UIWT program does is to determine if the SBC 416 board is in the card position on the SBC 416. If the SBC 416 is in place, the program finds a "1" located at address ØCØØØH. If it is not in this location, no transfer acknowledge signal will be returned. After a millisecond, therefore, the attempt is aborted and a "ØØ" is read into the 8080's accumulator. The ØØ occurs due to the 1K pullups on the inputs of inverting line drivers. With a 1 found at ØCØØH, the test program is conducted, while if a ØØ is returned, the normal UIWT program starts.

The 80/20 test signals its completion by turning on a "LED" located near the top right corner of the 80/20 barod. If no flashes are noted, the test was completed in a satisfactory manner. If flashes occur, some trouble was uncovered, the nature of which is indicated by the number of quick flashes grouped together. The trouble code is:

1 FLASH	==	RAM FAILURE
2 FLASHES	==	ROM FAILURE
3 FLASHES	==	I/O FAILURE
4 FLASHES	==	TIMER TOO SLOW
5 FLASHES	==	TIMER TOO FAST
6 FLASHES	==	USART FAILURE

A TIMER TOO FAST

6 FLASHES == USART FAILURE

A flash group is sent for each failure detected, so it is possible that more than one trouble code may be detected during a single 80/20 test. The test may be terminated only by turning off the power. This should be done, of course, before any physical changes are made to the computer.

b. IFB SELF TEST

To test the interface board, the 80/20 test SBC 416 board may be removed from the card cage and the IFB reinserted. The normal 50 pin rifle input strap connector and the 34 pin strap connector must be removed. A special strap must be connected between the 50 pin rifle test simulator output and the 50 pin rifle input connector.

The CRT and Electronic Data Terminal, EDT, are needed for the test. The VOTRAX unit may optionally be disconnected or left connected.

To conduct the test, the UIWT system is started as usual by a start or reset. When the query "WANT ID YES OR NO?" is presented on the EDT, a control-T for "TEST", should be entered. The system should respond with:

RIFLE SIMULATOR
STRAP IN PLACE?

If no errors are found, the test requires 18 to 19 seconds to run, and the system responds with:

TEST COMPLETE.

Hitting any key on the data terminal will result in the standard output being typed out, as shown in the attached listing.

If trouble is detected, the rifle "ID" number will be typed with "F" for failure and a coded diagnostic: RES, INT or DAT.

RES == The rifle did not receive a reset pulse.

INT == The UPI-41 did not receive the data strobe that it originally sent.

DAT == Improper data was received by the UPI-41.

H. FILM ANIMATION

This section describes the process by which a second projection film is produced to enable the electro-optic rifle receiver to sense targets on the movie screen and score the trainee's performance.

A black-and-white animated companion film is prepared for simultaneous syncronized projection on an infrared projector with a full color battle scenario on a second projector. The black-and-white film is animated frame-by-frame to produce a clear target zone surrounded by an opaque field. If more than one target is present then more than one clear target zone is animated within a frame.

Infrared light is projected through the clear target area to produce a target zone for the rifle electro-optic sensors. This infrared target zone is usually animated to directly overlay the visual target being projected by the full color battle scenario but may also be superelevated and/or lead the target as required.

Film animation has been accomplished by inspecting a battle scenario frame-by-frame on a Movieola (a type of laboratory film analyzer). Each frame is inspected for the total number of targets, and target location. Each frame is catalogued and then compared to each other for target range and rate of transverse motion measured. Lead and superelevation calculations are computed from this data for final animation.

Selected target shapes and sizes are prepared for use in the animation process. These shapes have usually been silhouette, oval, and circles. The target shape is realized as an opaque shape on a clear strip of acetate.

The battle scenario is again viewed frame-by-frame in the animation process. The animator locates targets according to the script and overlays on appropriate target size and shape on a rear projection screen. Lead and superelevation corrections are applied if necessary and then the battle scenario is removed while a single frame of the animated film is exposed.

Upon completion the entire animated film is developed using a reversal process. This process causes the opaque target shapes to become transparent and the background to be opaque. The contrast is adjusted for a D* = 2.5 or better. A D* of 2.0 has been used successfully.

Copies are made of this master animated film and both battle scene and the animated films are edge numbered for easy identification and editing. A final coat of laquer is then added to protect the emulsions and extend the life of the films.

The resolution of man targets beyond 300 meters is difficult and is a limitation of the system using standard 16mm film.

No research was done on automating the production of the IR target film. It is our opinion that research in this area could reduce both the time and expense of producing the infrared target film.

SECTION IV

CONCLUSIONS

The UIWT was tested usccessfully by the U.S. Marine Corps and by the U.S. Army, under the different name SWAT (Squad Weapons Analytical Trainer). The two systems are virtually identical except for the number of trainee firing positions. UIWT has four firing positions while SWAT consists of five firing positions.

Evaluation of the UIWT's training effectiveness and potential was performed in November 1979 at Camp Lejeune, North Carolina, by the U.S. Marine Corps. The evaluation was conducted by three members of Code N-241, Naval Training Equipment Center. Three different groups of Marines acted as test subjects or provided expert opinion. They are as follows:

(a) 120 enlisted men took part in a quasi-experiment designed to determine benefits of the UIWT versus a more traditional training method,

(b) Eight highly experienced snipers evaluated the UIWT for its training capabilities. These Marines also serve as marksmanship instructors,

(c) A variety of General, Field and Company grade officers fired the simulator and gave opinions concerning its usefulness.

The following comments on testing are extraced from Reference (8). Generally, the infantrymen were very positive about their experience with the UIWT. They would like to see deployment of the device into actual training situations. An overwhelming number stated that they would rather train in the UIWT than on the pop-up range. The elements of realism and immediate feedback were the main reasons for infantrymen satisfaction with the UIWT.

Without exception the officers who fired and observed the UIWT opined that it was a valuable training tool. Some officers went so far as to request that the UIWT prototype remain at Camp Lejeune so that they could start training Marines. A number of officers expressed concern about UIWT maintainability and reliability. They felt that if the UIWT was to be used for large numbers of trainees it would have to have rigid specifications for reliability.

The Marines suggested that there were no special features of the UIWT system (i.e., feedback, recoil, instructor console, infrared monitor, etc.) which should be deleted. All features seemed acceptable and desirable to those who evaluated the system.

The UIWT functioned well throughout the study. Breakdowns and malfunctions occurred on few occasions. This performance record is even more impressive when it is considered that this version of the UIWT is a prototype. The maintainability and reliability of the UIWT, based upon this evaluation, must be considered as good. Future iterations in the production format should only serve to increase these two characteristics.

Despite test limitations, the UIWT evaluation was considered to be successful by those participating in the evaluation. The overwhelming enthusiasm for the training device, exhibited by the Marine personnel who fired it and observed it, gave evidence of tis potential usefulness.

The evaluation of the UIWT at Camp Lejeune produced positive findings. Every characteristic of the UIWT met with approval. An evaluation of trial scores on the UIWT provided empirical evidence of the UIWT's effectiveness.

No formalized Program of Instruction (POI) exists for team firing training. Consequently, none was administered with the UIWT evaluation. This area of training should be given consideration in the future. Presently the instructor merely gives informal directions on how a fire team should function. The same informal procedure is followed for marksmanship instruction. Observation of the UIWT evaluation identified a number of factors which should be formally addressed in instruction for team fire.

(a) How large is a fire sector?

(b) Enemy tactics (i.e., Warsaw Pact, Vietnamese)

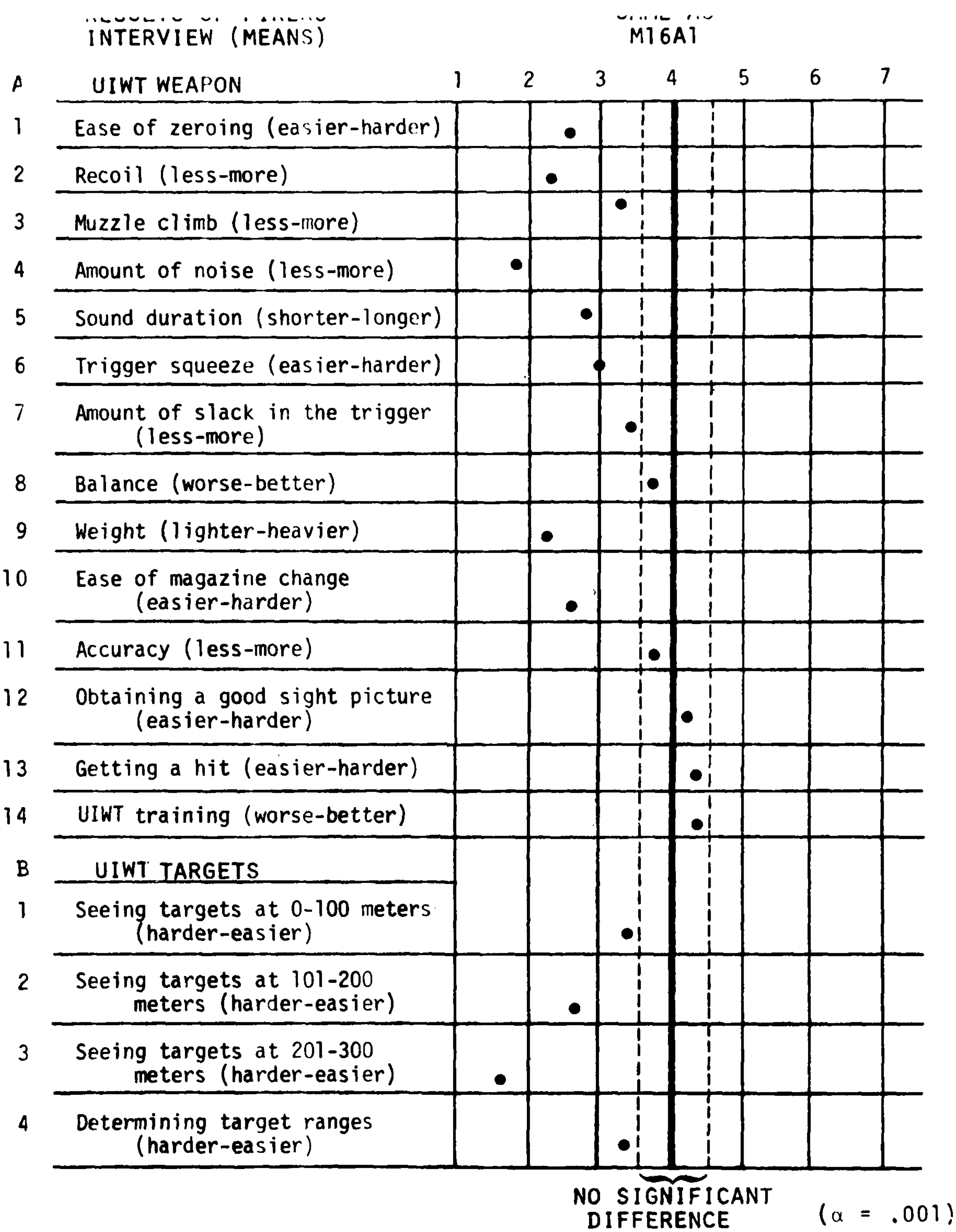
(c) Ammunition rationing

(d) Change in fire team tactics if a member is made inoperable (i.e., gun jams or casualty)

There is presently no training which accomplishes the objectives that the UIWT addresses (e.g., fire team training, on board ship practice and training, and providing realistic combat scenarios which require application of proper aiming techniques). Since the Marine Corps deems these objectives to be important, it is recommended that the UIWT effort be funded and prepartion be made for contractor production of the system. In addition, development of the UIWT's capability to simualate other infantry weapons such as the TOW, DRAGON, motars, etc., should continue. Also, any formalized instruction should include techniques for firing at moving targets (including leading, firing into brush cover, and firing through smoke). It is possible for an instructor to forget to cover many of these important points when it is presented in an informal manner.

The UIWT has a counter which allows the number of rounds fired during a session to be accurately assessed. This counter showed that over 40,000 electronic rounds were used for the evaluation. Presently, costs for live M-16 ammunition are approximately nine cents per round. At this rate, the UIWT accomplished an ammunition cost savings of nearly $4,000. This figure if applied to a year's worth of training, would be a significant savings. At this rate the UIWT would pay for itself in a year. If the transportation fuel costs were added to the ammunition cost the savings would be even more impressive.

The U.S. Army test was conducted by the U.S. Army Infantry Board (USAIB) for the Directorate of Training Developments, U.S. Army Infantry School (USAIS), Fort Benning, Georgia (See Reference 9). The test was conducted 22 January through 5 March 1980, employing test soldiers from the U.S. Army Marksmanship Unit and TOE units. Testing included use of the SWAT as a vehicle for training riflemen a technique of engaging moving personnel targets. A comparison of record fire scores, achieved by personnel trained on the SWAT, on the Infantry Remoted Target System, Defense Test Range, and a no-training control group, was conducted to address training potential. Figure IV-1 indicates the results of firers interviews concerning the SWAT weapon and SWAT targets. Some of the major findings were that test soldiers improved their firing performance on three iterations of SWAT firing, but not on three iterations of DTR firing. It is stated that "this test does give some evidence of the SWAT system's potential for training transfer. However, a final estimate of the systems training value cannot be made until a training program is developed which optimizes SWAT performance".



Note: In all cases the UIWT rifle and targets are being compared to the M16A1 and the DTR range. If there was no difference between them, then a 4 was chosen. The farther away the mean is from 4, the more difference there is between the UIWT and the M16A1.

Figure IV-1. Results of Firers' Interview (Means)

REFERENCES

1. CT 8101 Printing Terminal User's Instruction Manual, Tektronix, Inc., Beaverton, Oregon, May 1977. A manual covering the Texas Instruments Model 743 Electronic Data Terminal.

2. Marshall, Albert H., Herbert C. Towle, Bon F. Shaw, "Electro-Optic Infantry Weapons Trainer," 10th Annual Electro-Optic/Laser 78 Conference and Exposition, September 1978 Sponsored by the Laser Institute of America (LIA).

3. McCracken, D. D., "A Guide to P./M Programming For Microcomputer Applications," Addison-Wesley Publishing Company, Reading, Mass, 1978.

4. MCS-48 Microcomputer User's Manual, Intel Order Number 9800270D, July 1978.

5. PL/M-80 Programming Manual, Intel Order Number 98-268, Intel Corporation, Santa Clara, 1976.

6. System 80/20-4 Microcomputer Hardware Reference Manual, Intel Order Number 980484A, Intel Corporation, Santa Clara, 1977.

7. UPI-41 User's Manual (Preliminary), Intel Order Number 9800504A.

8. Universal Infantry Weapons Trainer Evaluation, Report No. N-2411P11-A/2-79, N-241 Instructional Concepts Development Branch.

9. Maj. J. Fagersten, Maj. G. Bishop, Mr. M. Wasson and Ms. E. Redden, Concept Evaluation Test Squad Weapons Analytical Trainer, Final Report, U.S. Army Infantry School, Ft. Benning, GA.

APPENDIX A

FUNCTIONAL DESCRIPTION OF CONSOLE SWITCHES

APPENDIX A

FUNCTIONAL DESCRIPTION OF CONSOLE SWITCHES

Figure A-1 displays the Instructor's Console. The right side display screen presents printed columns showing trainees results each time they fire, and indicates by a red light which trainee is doing the poorest. The miniature toggle switches must be in the up (or on) position for any trainee participating in the exercise. The left side display screen presents positions of movie targets and indicates where trainee is aiming and where his round has been fired in relation to where the target appeared.

On the main, center panel, the instructor operated switches are arranged and labeled in groups by function. They are:

1. Main power (single switch)
2. Microcomputer (three switches)
3. Computer Voice (two switches)
4. Projector (two switches)
5. Motor (three position rotary switch)
6. Boresite (single switch)
7. Recoil (single switch)
8. Score display (single switch)
9. Audio Communications (eleven switches)
10. Weapon motion system (eleven switches)

The operation of these switches follows:

<u>MAIN POWER</u> - Applies the ac power to entire console.

<u>MICROCOMPUTER</u> - "On" applies operating voltages to computer.

"Reset" clears all previous data from computer and asks if individual identification of each trainee is required. If none is required, depress any key except Y (For "yes"). Computer will signify system is ready by printing out "let's start".

"Start print" starts the hard copy printout process printing trainees results and analysis.

If individual scoring identification is required, depress the letter Y on typewriter. Computer will ask you for today's date, session number and to enter in name of first trainee, then instruct you to identify the others in same manner. NOTE: Names of trainees must be limited to those containing no more than six letters.

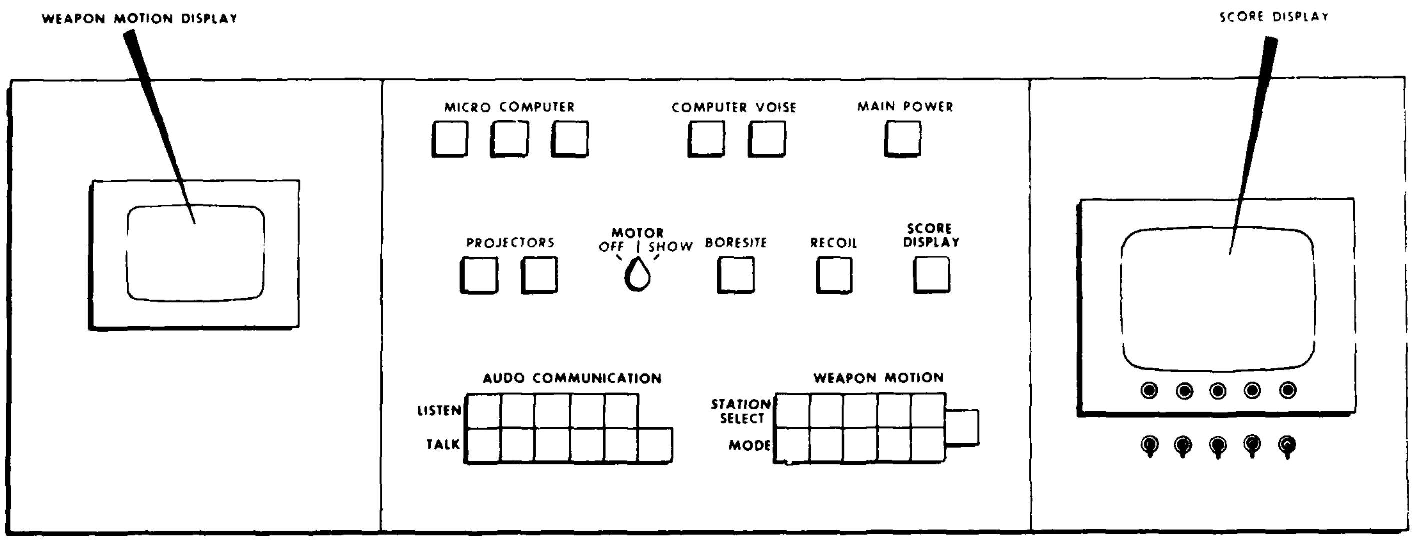


Figure A-1. Instructor's Console - Front Panel Control Locations

COMPUTER VOICE - Permits instructor to activate the computer voice carried to trainee headphones. The voice reset button should be pushed whenever the computer voice is turned on.

PROJECTORS - "Locked-Unlocked" switch either locks or unlocks synchronous motors of IR and visual projectors together so that target frame and visual frame coincide, or permits instructor to operate projectors independently during alignment. For normal operation the switch should remain locked.

"Start Movie" physically starts the movie if motor switch is not in off position.

MOTOR - This three position rotary switch performs the function of applying ac power first to projector motor and then to projector lamps (this procedure is conventional in all movie projectors to conserve lamp life).

BORESIGHT - This switch allows instructor to override the "target present" signal delivered to computer by the projector, so that trainees can fire at the target box instead of the movie screen. When lower half of this switch is illuminated the system is in normal (movie screen) position.

RECOIL - This switch gives instructor the option to conduct exercise with or without rifle recoil.

SCORE DISPLAY - This switch clears the right side screen display.

AUDIO COMMUNICATIONS - This bank of eleven switches permits the instructor to listen in on the headphone of any trainee, and talk to any one or all trainees.

WEAPON ACTION SYSTEM - This bank of eleven switches allows the instructor to view, on the left side display screen, exactly where any, or all, trainees are aiming and firing in relation to where targets appeared on movie screen. The upper bank of switches selects the trainee to be observed. The lower bank of switches either energizes a trainee's laser continually or only when he had fired his rifle. These switches supply operating power to the laser attached to each rifle, and must be held pushed in for the laser to operate.

APPENDIX B

TEST EQUIPMENT

APPENDIX B

TEST EQUIPMENT

1. LASER CHECKER

The laser checker test box, Figure B-1, allows instructor to make a go-or-go check of the UIWT tracking laser which is attached to the simulated rifle. Referring to the schematic, Q1 is a silicon photodiode which responds to IR energy from the rifle laser. When the rifle trigger is pulled, with the laser positioned a few inches from the detector, Q1 detects the infra red pulse, and delivers an output signal to Q2.

Q2 is a high gain amplifier whose output is a sharply rising positive pulse that provides the gating signal required to turn on silicon controlled rectifier Q3, placing its anode at ground potential, and allowing capacitor C3 to begin charging up toward Vcc through resistor R5, and energizes the Sonalert alarm producing an audio tone of approximately 2 KHz.

Q4 is a unijunction transistor oscillator which is enabled whenever capacitor C3 is returned to ground. As capacitor C3 starts to charge toward Vcc it produces an exponentially rising DC voltage at the emitter junction of Q4. When this voltage reaches the breakdown point for this particular unijunction, Q4, conducts heavily, shorting emitter to ground thereby allowing the charge on C3 to dissipate, lifting the anode of Q3 off of ground which turns off the SCR, disabling the audio alarm, and the entire circuit is again ready for recycling.

Power for the laser checker is externally provided via binding posts. Any battery voltage from six to thirty volts may be used. The audio alarm sound level varies with battery voltage. Fifteen volts provides more than adequate sound level for an average room.

2. RIFLE CHECKER

By using an ordinary penlite flashlight as a source of light energy, and directing the light into the lens of the rifle receiver, the rifle checker test box allows the instructor to confirm that the four quadrant detector in the rifle is functioning, the "Full Clip" feature of the UIWT system is operating correctly, that the rifle mode select switch, and rifle trigger switch, are also functioning properly. In addition, the UIWT laser can be tested using the laser checker in conjunction with the rifle checker.

Detector Test: Referring to the schematic of the rifle checker, Figure B-2. connections to the rifle are made via a T&B connector identical to that with the UIWT system. Connector pin numbers are identified on the schematic. IC1 is a quad comparator which establishes the signal strength reference level of the IR energy received. Each of the four comparators parameters are identical. The desired reference level is established on the non-inverting inputs of IC1. The rifle detector outputs appear as signal at the inverting inputs

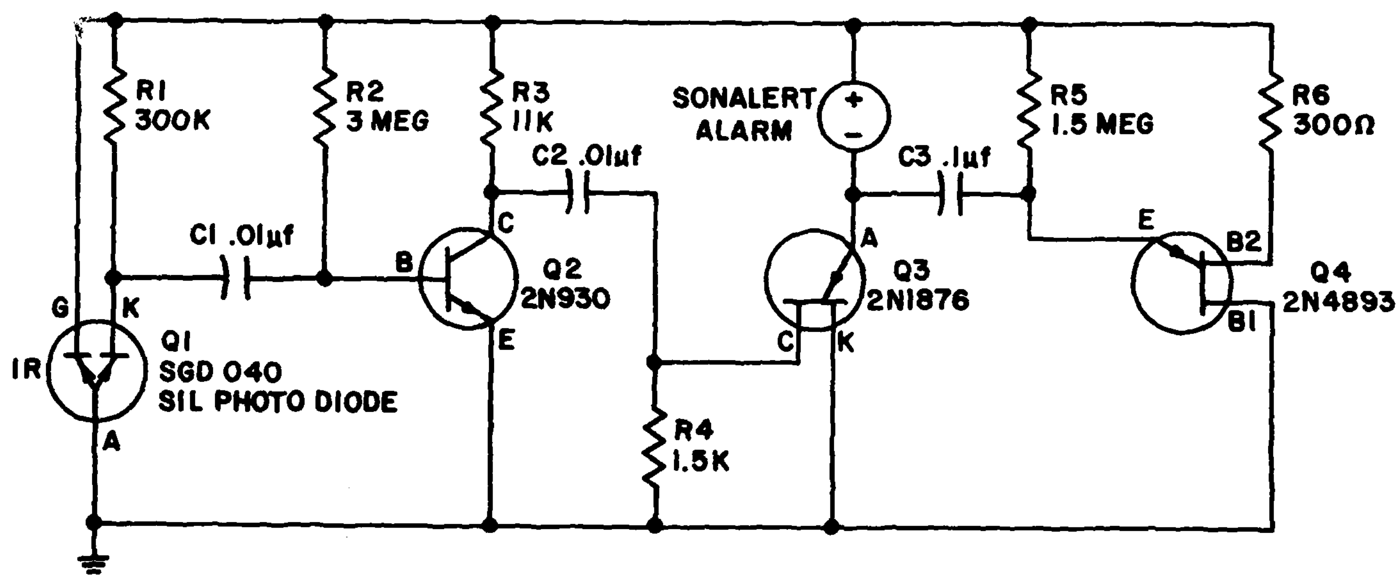


Figure B-1. Laser Defector Box

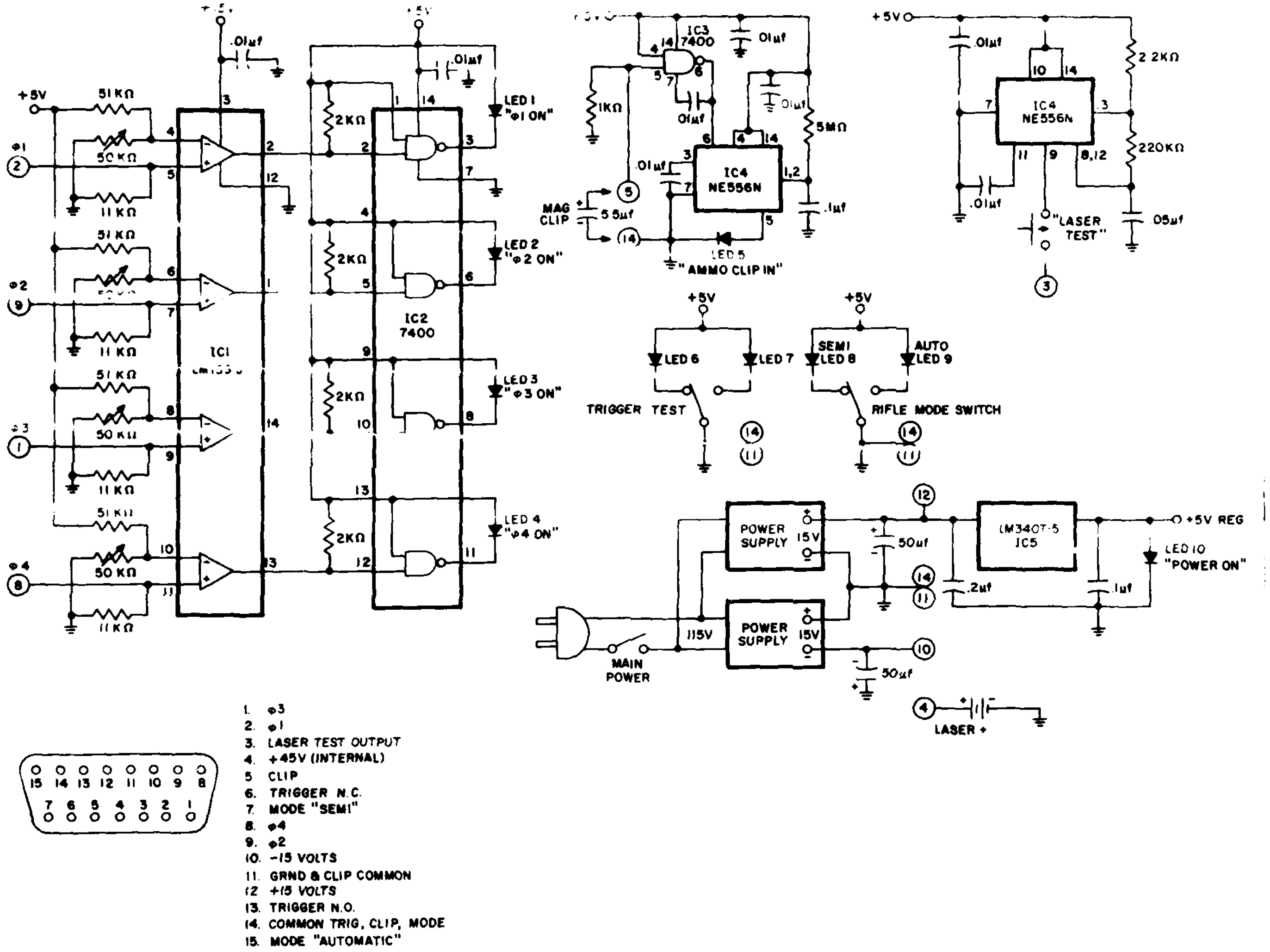


Figure B-2. Rifle Checker

of IC1. When this input signal is of an amplitude equal to the reference level established via the variable resistor, the outputs of IC1 rise to a logical "HIGH". This output "HIGH" signal appears on one input to IC2 which is a quad NAND gate. Since the remaining NAND inputs are permanently "HIGH", IC2 produces a logical "LOW" at its ouput, providing a path to ground for that particular LED, allowing it to light up, indicating that the UIWT rifle detector is operational. By pointing the flashlight beam into the rifle receiver lens and moving it about, it is possible to observe that all four quadrants of UIWT's rifle detector are indeed functioning.

Ammo Magazine Test: One half of IC4 is a timer arranged to produce one pulse of approximately five second duration whenever it receives an input, thereby testing the "full ammo magazine" feature of UIWT A "full magazine" is simulated by one whose internally-mounted capacitor has been charged. A separate, partitioned-holding/charging tray which accomodates up to 30 magazines is provided with the instructor's console. In future modifications, this holding/charging tray can be incorporated into the console. Referring to the schematic, when a (charged capacitor) full magazine is inserted in the rifle, the capacitor discharges into one gate of IC3, a NAND, providing a negative going signal as input to timer IC4. When IC4 turns on its output goes "HIGH" allowing LED 5 to light for approximately five seconds. If an "empty magazine (i.e. one which has expended its full thirty rounds) is inserted into the UIWT rifle, it cannot energize the circuit and LED 5 will not illuminate.

Laser Test: This test is performed by one half of IC4. The circuit is a free-running oscillator delivering sharp positive pulses of approximately one microsecond duration at a PRR of 5 KHz. This output is directly connected to the laser input via the normal connecting cable. When the "laser test" button on the rifle checker box is depressed, the output of oscillator IC4 is allowed to trigger the laser, and the laser will emit IR energy.

By setting up the laser checker* box several inches from the laser, an audio alarm tone indicates correct operation of the laser each time the test button is depressed. *Circuit operation is described in Paragraph 1 of this Appendix B.

Rifle Trigger and Mode Switch Test: Correct physical functioning of the UIWT rifle trigger is verified by observing the test lights LED 6 and LED 7. LED 6 will normally be on. When the rifle trigger is pulled LED 6 goes off for a fraction of time, LED 7 comes on during that instant, and as the trigger is pulled all the way LED 6 comes back on and remains on.

Rifle Mode Switch Test: The UIWT rifle mode select switch is tested by observing the operation of LED 8 and LED 9. In the semi-automatic mode, LED 8 is on and in the automatic mode LED 9 is on.

An internal dual fifteen volt power supply provides operating voltages for the UIWT as well as for the pre-amp receiver in the UIWT rifle. A single miniature dry cell forty-five volt battery within the test box supplies operating power for the UIWT laser.

3. RIFLE SUBSTITUTION BOX

Using the rifle substitution box, it is possible to simulate the operation of a UIWT rifle on the instructor's console. It can simulate a rifle being fired either in automatic or semi-automatic mode, and can simulate the target information normally received by the rifle's quadrant detector from the projected movie image.

The rifle substitution box is connected to the instructor's console via a T&B connector identical to that on a UIWT rifle. Power for the test box is derived from the console. Operation of the trigger switch and the mode switch are obvious. Capacitor C1 simulates the capacitor which is internally mounted inside of each magazine. It remains in the charged state via switch SW4 as long as the test box power switch is in the "on" position. When the counting circuit in the UIWT electronics indicates to the computer that thirty rounds have been expended by allowing no more shots, the insertion of a new magazine is simulated by momentarily engaging switch SW1.

Target information is simulated by the status of four switches, SW5, SW6, SW7, and SW8. IC1 is a free-running oscillator delivering a square wave at a PRR of 96 Hz (which is the rate at which the projected IR Target energy is chopped). The output of the oscillator is delivered to the console via switches SW5 through 8 as simulated rifle detector signals.

Referring to the schematic, Figure B-3, the adopted convention for the four quadrant rifle detector is shown. Switches may be independently thrown to either ground (low) or to the 96 Hz positive pulse output of IC1, constituting either a true or a false logic signal to the UIWT console. Any one of ten possible combinations of hit or near misses can be duplicated by these four switches. For example: Switches SW3, SW4 "Low" and switches SW1, SW2 "High" will be recorded by the computer as a "low right" signal from the simulated rifle. Similarly, SW1, SW4, SW2 "High" and SW3 "Low" would simulate a UIWT rifle detector condition where IR energy is centered on those quadrants. This information would be interpreted by the computer as a trainee having fired "Low" at the target.

4. BORESIGHT BOX

The boresight box, Figure B-4, allows the instructor to initially check the closeness of UIWT rifle boresight alignment. A free running oscillator IC1 with a PRR of 96 Hz delivers input pulses to a Darlington amplifier which consists of Q1 and Q2. The Darlington amplifier pulses a high intensity incandescent lamp at 96 Hz. The visible portion of light is filtered out so the rifle is aimed at the black-outlined aiming pip on the box, fires the weapon, receives audio

feedback results via his headphones, and adjusts rifle sights for accurate alignment of front and rear sights.

Power for the boresight box is supplied externally via one small, 12 volt rechargeable sealed-gel battery. The boresight box can also be utilized as a marksmanship target. The instructor simply enables the front panel "target present" switch allowing the UIWT console to disregard target information from the movie screen, and instead, to accept target information from the boresight box.

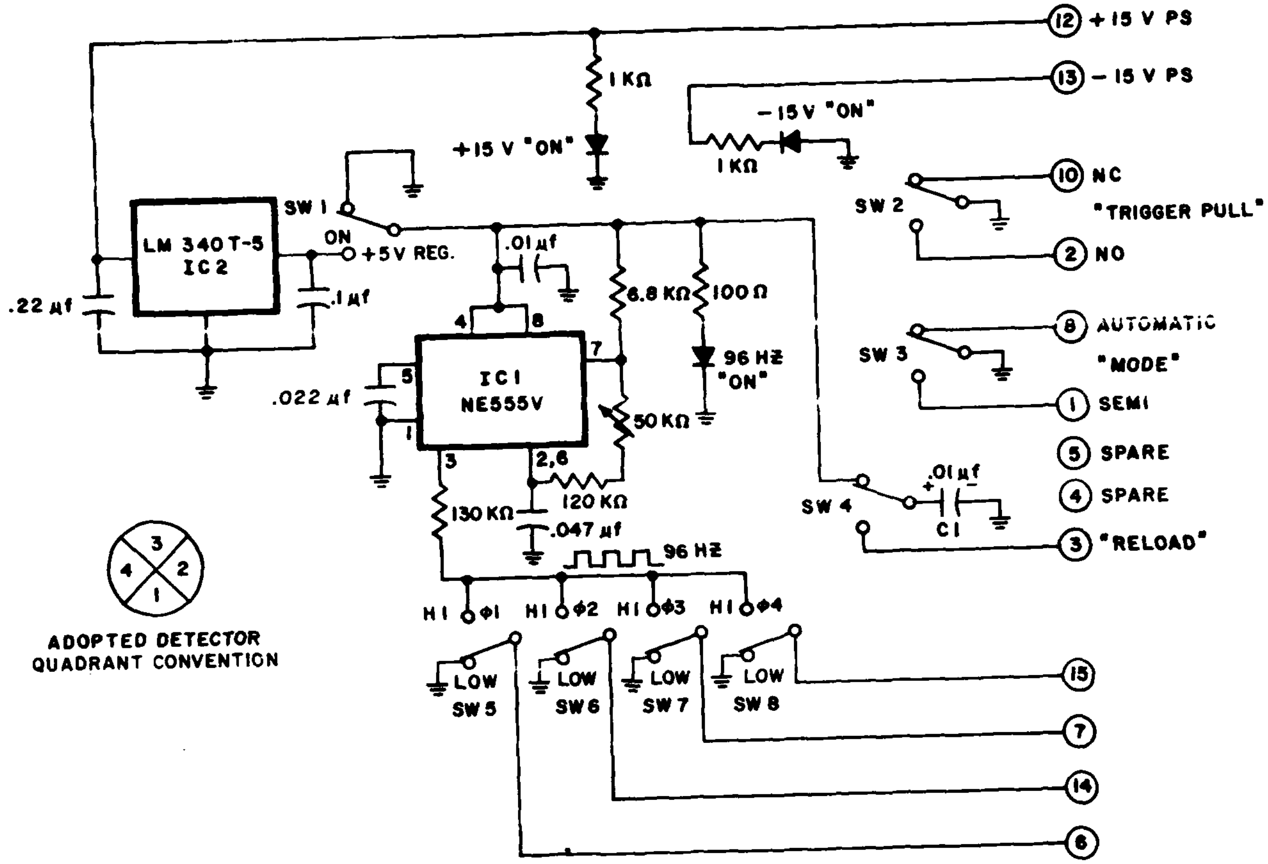


Figure B-3. Rifle Substitution Box

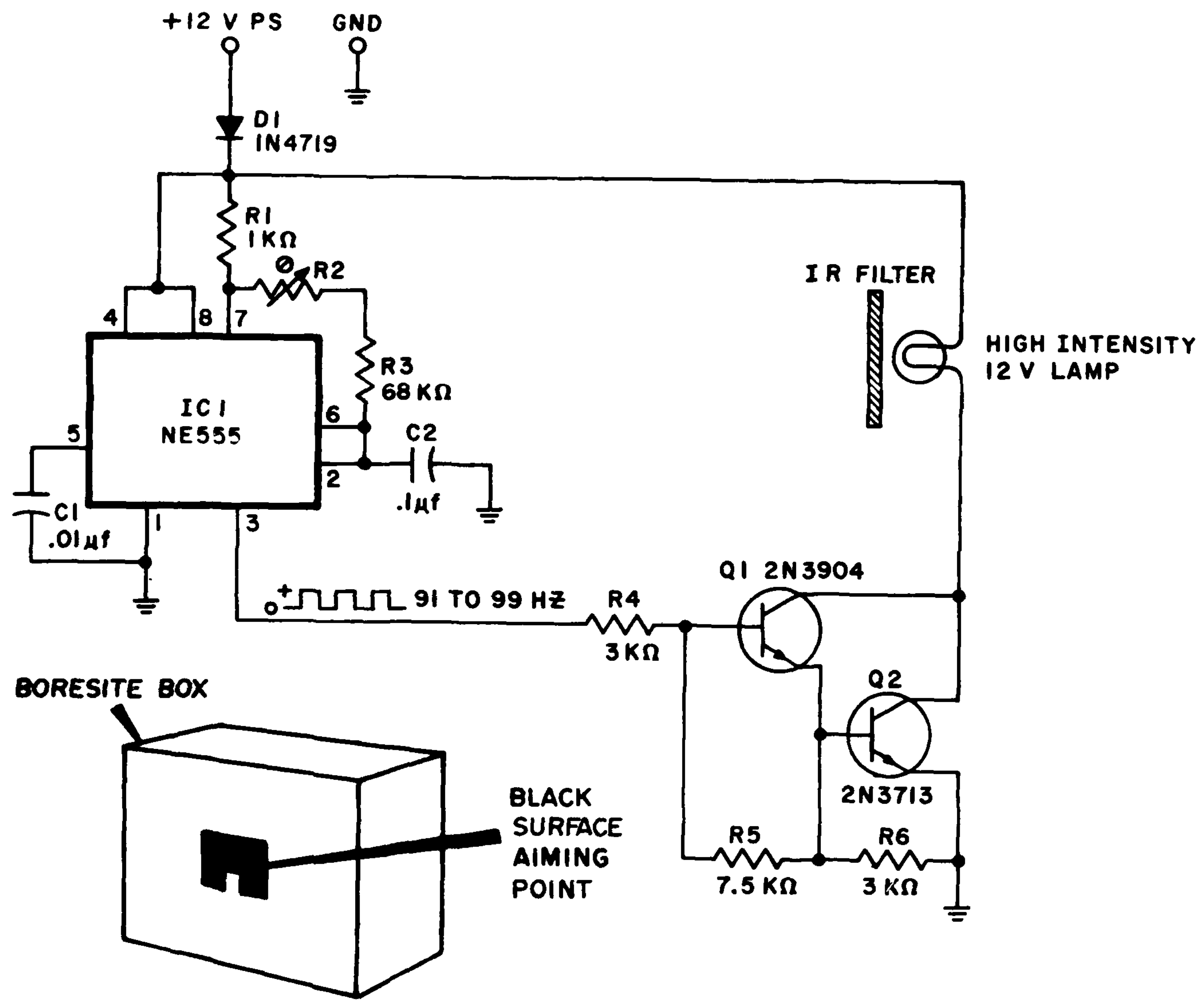


Figure B-4. Boresight Box

APPENDIX C

SYSTEM PROGRAM

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-LOCATE  F1 UINT IMP TO  F1 UINT  YMBOL  LINES MAP PRINT  F  UTH  PRT

SYMBOL TABLE OF MODULE UINT
READ FROM FILE  F1 UINT MP
WRITTEN TO FILE  F1 UINT

VALUE TYPE SYMBO

       MOD   MAINU WIMODULE
191 H SYM   MEMORY
0000H SYM   LEAR ACCUMULATOR
1800H SYM   TRAINING
1801H SYM   IF
1800H SYM   TRAIN
00E H SYM   TURE  TEST
1802H SYM   TARGE DOWNTIME
1804H SYM   TARGE EJECTED
1805H SYM   IFLAG
1806H SYM   FFALG NE
1807H SYM   TURE
1808H SYM   ARGE  TIME
0004H SYM   ESTE ARDCHECK
000EH SYM   INTE UGRAM
000EH SYM   NITIALIZE
0027H SYM   ESSI N
00 LH SYM   ACTION
0042H SYM   OTONE
004AH SYM   NEWONE
0064H SYM   GOOD TH
00FAH SYM   OUTARGET
00 H SYM   NOACTION
00 AH SYM   IGONE
00 H SYM   WAITONE
0046H SYM   RECOR GONE
00 EH SYM   ENDING
00BEH LIN     4
00BEH LIN     4
00CAH LIN     4
00D9H LIN     4
00EBH LIN     4
00F H LIN     4
00FEH LIN     4
00 H LIN     4
00 H LIN     5
0004H LIN     5
000EH LIN     5
000EH LIN     5
000EH LIN     6
0011H LIN     6
0014H LIN     6
0017H LIN     6
001AH LIN     6
001DH LIN     6
0027H LIN     6
002EH LIN     6
002CH LIN     6
00 CH LIN     6
004 H LIN     7
004 H LIN     
004AH LIN     
004 H LIN     
00 AH LIN     
00 H LIN     5
00 H LIN     5
00 H LIN     
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005DH LIN    78
0064H LIN    79
0067H LIN    80
006AH LIN    81
006AH LIN    82
006DH LIN    83
0070H LIN    84
0070H LIN    85
0073H LIN    86
0073H LIN    87
007AH LIN    88
007AH LIN    89
0080H LIN    90
0085H LIN    91
0085H LIN    92
008CH LIN    93
008CH LIN    94
008FH LIN    95
0096H LIN    96
0096H LIN    97
009BH LIN    98
009EH LIN    99
00A9H LIN   100
00ACH LIN   101
00ACH LIN   102
00ACH LIN   103
00ACH LIN   104
00AFH LIN   105
00B2H LIN   106
00B5H LIN   107
00B9H LIN   108
00BCH LIN   109
      MOD   STARTUPMODULE
391FH SYM   MEMORY
13FCH SYM   INTERRUPTCALL
380AH SYM   HISTORY
380FH SYM   NAME
383CH SYM   DATE
3848H SYM   IDNUMBER
0104H SYM   WHEN
0114H SYM   UIWTID
0129H SYM   IDENT
013CH SYM   QUERY
0152H SYM   TRAINEES
016CH SYM   ONRIFLE
384FH SYM   X
3850H SYM   I
3851H SYM   J
3852H SYM   K
3853H SYM   JK
3854H SYM   IDFLAG
0176H SYM   PORTSET
017FH SYM   SETDATA
3855H SYM   POINTER
3857H SYM   LENGTH
3858H SYM   VALUE
3859H SYM   FINAL
0199H SYM   LOOP
01B7H SYM   SIMULATERIFLES
385BH SYM   RUNTYPE
01BFH SYM   STARTUP
024CH SYM   SETINT
02A2H SYM   GETID
02A7H SYM   CLRDATE
02C2H SYM   GETDATE
032AH SYM   GETIDNUMBER
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UNIVERSAL INFANTRY WEAPONS TRAINER (UIWT). VOLUME 1. M-16 RIFLE--ETC(U)
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[illegible]7H	SYM	ONENAME
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01[illegible]6H	LIN	23
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01[illegible]FH	LIN	29
01[illegible]CH	LIN	31
01[illegible]9H	LIN	32
01A5H	LIN	33
01ACH	LIN	34
01B[illegible]H	LIN	35
01B6H	LIN	36
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01[illegible]7H	LIN	42
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01[illegible]FH	LIN	46
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01[illegible]0H	LIN	50
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01[illegible]BH	LIN	53
0[illegible]00H	LIN	54
0205H	LIN	55
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0[illegible]3DH	LIN	65
0[illegible]41H	LIN	66
0[illegible]48H	LIN	67
0[illegible]49H	LIN	68
0[illegible]4CH	L[illegible]N	69
0[illegible]50H	LIN	70
[illegible]54H	LIN	71
0[illegible]58H	LIN	72
0[illegible]5DH	LIN	7[illegible]
0[illegible]62H	LIN	74
0[illegible]67H	LIN	[illegible]5
0[illegible]6DH	LIN	[illegible]
0[illegible]72H	LIN	[illegible]
[illegible]78H	LIN	[illegible]
[illegible]27EH	LIN	[illegible]
[illegible]284H	LIN	[illegible]1
[illegible]28BH	LIN	[illegible]
[illegible]290H	LIN	[illegible]
[illegible]295H	LIN	[illegible]
[illegible]29AH	LIN	[illegible]5
[illegible]2A2H	LIN	[illegible]
[illegible]2A2H	LIN	[illegible]
[illegible]2A[illegible]H	LIN	[illegible]
[illegible]2B2H	LIN	[illegible]
[illegible]2B8H	LIN	[illegible]
[illegible]2BDH	LIN	[illegible]1
[illegible]2[illegible]2H	LIN	[illegible]2
[illegible]2[illegible]0H	LIN	[illegible]
[illegible]2D6H	LIN	[illegible]4
[illegible]2[illegible]FH	LIN	[illegible]

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02EAH LIN     97
02F7H LIN     98
02FEH LIN     99
0303H LIN    100
0308H LIN    101
030DH LIN    102
0318H LIN    103
031EH LIN    104
0323H LIN    105
0326H LIN    106
032BH LIN    107
0339H LIN    108
033FH LIN    109
0347H LIN    110
034CH LIN    111
0353H LIN    112
0360H LIN    113
0367H LIN    114
036CH LIN    115
0371H LIN    116
0376H LIN    117
0381H LIN    118
0387H LIN    119
0395H LIN    120
039BH LIN    121
03A4H LIN    122
03A9H LIN    123
03AEH LIN    124
03B3H LIN    125
03B6H LIN    126
03C7H LIN    127
03D5H LIN    128
03DBH LIN    129
03E3H LIN    130
03E8H LIN    131
0403H LIN    132
040AH LIN    133
0411H LIN    134
0416H LIN    135
042BH LIN    136
0430H LIN    137
0437H LIN    138
0437H LIN    139
043FH LIN    140
0442H LIN    141
      MOD  TIMERMODULE
391FH SYM  MEMORY
385CH SYM  LSTIMEBYTE
385DH SYM  MSTIMEBYTE
385EH SYM  TIME
385EH SYM  LOWTIMEBYTE
385FH SYM  HIGHTIMEBYTE
0443H SYM  TIMERSTART
045CH SYM  TTYTIMER
0469H SYM  VOTRAXTIMER
0476H SYM  CLOCKREAD
0443H LIN      8
0443H LIN      9
0447H LIN     10
044BH LIN     11
044FH LIN     12
0453H LIN     13
0457H LIN     14
045BH LIN     15
045[illegible]H LIN     16
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0460H LIN    18
0464H LIN    19
0468H LIN    20
0469H LIN    21
0469H LIN    22
046DH LIN    23
0471H LIN    24
0475H LIN    25
0476H LIN    26
0476H LIN    27
047AH LIN    28
047FH LIN    29
0484H LIN    30
0488H LIN    31
      MOD  RIFLEDATAMODULE
391FH SYM  MEMORY
3860H SYM  MESSAGE
0498H SYM  SCORIT
3861H SYM  SHOTLOCATION
3862H SYM  FILE
0488H SYM  DECODE
3863H SYM  FIRSTSHOT
3868H SYM  SCORE
3868H SYM  ADDER
38A9H SYM  SPEED
38B8H SYM  TOTALTIME
38BAH SYM  DELTATIME
38BCH SYM  FILE
38BDH SYM  RIFLE
38BEH SYM  FPTR
38BFH SYM  SHOTFLAG
38C0H SYM  RIFLEID
04B7H SYM  UPISTROBE
04C0H SYM  TARGETAVAILABLE
38C1H SYM  TARGET
04C6H SYM  RIFLESHOT
04CCH SYM  GETRIFLEDATA
38C2H SYM  SHOTDATA
04CCH SYM  UNRESOLVED
04DAH SYM  WHOSHOT
0521H SYM  HOWQUICK
05D4H SYM  OKDATA
05FDH SYM  VOTAXMESSAGES
068CH SYM  TURKEYDATA
06F2H SYM  WHOFAILEDTOSHOOT
076AH SYM  SHOWWORST
38C3H SYM  BADWORD
38C4H SYM  BADNEWS
076AH SYM  HOWBAD
07D1H SYM  HUNTWORST
0498H LIN     6
049EH LIN     8
04E?H LIN     9
04E?H LIN    11
04E?H LIN    12
04EBH LIN    13
04EFH LIN    14
04C0H LIN    15
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04CEH LIN    42
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0521H LIN    57
0521H LIN    58
052DH LIN    59
053CH LIN    60
054EH LIN    61
056DH LIN    62
057DH LIN    63
0588H LIN    64
0588H LIN    65
0588H LIN    66
0593H LIN    67
059BH LIN    68
059FH LIN    69
05A4H LIN    70
05A8H LIN    71
05B2H LIN    72
05B6H LIN    73
05BAH LIN    74
05BFH LIN    75
05C8H LIN    76
05D4H LIN    77
05D4H LIN    78
05EEH LIN    79
05FAH LIN    80
05FDH LIN    81
060DH LIN    82
0615H LIN    83
061DH LIN    84
0625H LIN    85
0625H LIN    86
062AH LIN    87
062FH LIN    88
0632H LIN    89
063AH LIN    90
063AH LIN    91
063FH LIN    92
0644H LIN    93
0647H LIN    94
064FH LIN    95
064FH LIN    96
0654H LIN    97
0659H LIN    98
065CH LIN    99
0664H LIN   100
0664H LIN   101
0669H LIN   102
066EH LIN   103
0671H LIN   104
0685H LIN   105
0685H LIN   106
068CH LIN   108
06A0H LIN   109
06AAH LIN   110
06ADH LIN   111
06B2H LIN   112
```

```
06B?H LIN    11?
06B7H LIN    114
06C7H LIN    116
06D7H LIN    117
06E1H LIN    118
06E4H LIN    119
06E9H LIN    120
06E9H LIN    121
06EEH LIN    122
06F1H LIN    123
06F2H LIN    124
06F2H LIN    125
0700H LIN    126
070AH LIN    127
0719H LIN    129
072DH LIN    130
0737H LIN    131
073AH LIN    132
073FH LIN    133
0748H LIN    134
074DH LIN    135
0752H LIN    136
0757H LIN    137
0757H LIN    138
075EH LIN    139
0769H LIN    140
076AH LIN    141
076AH LIN    144
0778H LIN    145
0783H LIN    146
0798H LIN    147
07C0H LIN    148
07C7H LIN    149
07CCH LIN    150
07D1H LIN    151
07DFH LIN    152
07F8H LIN    153
0808H LIN    154
0821H LIN    156
0829H LIN    157
0832H LIN    158
0832H LIN    159
0839H LIN    160
083EH LIN    161
      MOD   CONSOLEMODULE
391FH SYM   MEMORY
083FH SYM   HELLO
38C9H SYM   I
38CAH SYM   Y
38CBH SYM   GOS
0851H SYM   TTYSET
0869H SYM   TTYRES
0871H SYM   VOTRAXSET
087AH SYM   VOTRES
0891H SYM   CIN
0891H SYM   RXRDY
08A1H SYM   TXRDY
08AFH SYM   COUT
38CCH SYM   ITEM
08C2H SYM   BITDUMP
08C8H SYM   PRNTNUM
0912H SYM   PRINT
38CDH SYM   POINTER
38CFH SYM   FINAL
0925H SYM   LOOP
0943H SYM   GREETING
```

```
[illegible] LIN      9
0851H LIN      10
0855H LIN      11
0859H LIN      12
085DH LIN      13
0860H LIN      14
0864H LIN      15
0868H LIN      16
0869H LIN      17
0869H LIN      18
086DH LIN      19
0870H LIN      20
0871H LIN      21
0871H LIN      22
0875H LIN      23
0879H LIN      24
087AH LIN      25
087AH LIN      26
087EH LIN      27
0882H LIN      28
0886H LIN      29
088AH LIN      30
088DH LIN      31
0890H LIN      32
0891H LIN      33
0891H LIN      34
0899H LIN      35
089CH LIN      36
08A1H LIN      37
08A1H LIN      38
08A1H LIN      39
08ABH LIN      40
08AEH LIN      41
08AFH LIN      42
08B3H LIN      44
08B9H LIN      45
08BCH LIN      46
08C1H LIN      47
08C2H LIN      48
08C2H LIN      49
08C7H LIN      50
08C8H LIN      51
08C8H LIN      52
08CDH LIN      53
08DBH LIN      54
08EDH LIN      55
08F2H LIN      56
08F9H LIN      57
0900H LIN      58
0907H LIN      59
090CH LIN      60
0911H LIN      61
0912H LIN      62
0918H LIN      64
0925H LIN      65
0931H LIN      66
0938H LIN      67
093FH LIN      68
0942H LIN      69
0943H LIN      70
0943H LIN      71
0949H LIN      72
094CH LIN      73
094DH LIN      74
      MOD  RESULTSMODULE
391FH SYM  MEMORY
```

```
38D[illegible]H SYM  [illegible]
38D[illegible]H SYM  I
38D[illegible]H SYM  Z
38D[illegible]H SYM  SUMSHOTS
38D7H SYM  NEARMISSES
38D8H SYM  AVGTIME
0A24H SYM  CONVRT
38DAH SYM  HEX
094EH SYM  RIFLEID
0956H SYM  TOTALSHOTS
0964H SYM  RIFLEHIT
096BH SYM  RIFLEMISS
0974H SYM  RIFLELOW
097BH SYM  RIFLELOWRIGHT
0988H SYM  RIFLERIGHT
0991H SYM  RIFLEHIGHRIGHT
099FH SYM  RIFLEHIGH
09A7H SYM  RIFLEHIGHLEFT
09B4H SYM  RIFLELEFT
09BCH SYM  RIFLELOWLEFT
09C8H SYM  RIFLETURKEY
09D4H SYM  RIFLETARGETIGNORED
09E6H SYM  BLANK
09E9H SYM  HOWMANYSHOTS
09FBH SYM  AVERAGETIME
0A0AH SYM  UNITS
0A12H SYM  YOURSCORE
0A6EH SYM  PRESENTRESULTS
0A9DH SYM  ONERIFLERESULTS
0AC2H SYM  TYPEIT
0B24H SYM  SUM
0B5CH SYM  SUM2
0A24H LIN      24
0A28H LIN      26
0A36H LIN      27
0A56H LIN      28
0A66H LIN      29
0A6DH LIN      50
0A6EH LIN      51
0A6EH LIN      52
0A6FH LIN      53
0A72H LIN      54
0A78H LIN      55
0A7EH LIN      56
0A85H LIN      58
0A8BH LIN      59
0A91H LIN      60
0A91H LIN      61
0A97H LIN      62
0A9DH LIN      63
0AABH LIN      64
0AC2H LIN      65
0AC2H LIN      66
0AC8H LIN      67
0ACEH LIN      68
0AD7H LIN      69
0ADDH LIN      70
0AE3H LIN      71
0AEAH LIN      72
0B00H LIN      73
0B06H LIN      74
0B0CH LIN      75
0B12H LIN      76
0B19H LIN      77
0B1FH LIN      78
0B24H LIN      79
```

```
0B32H LIN      80
0B50H LIN      81
0B57H LIN      82
0B5CH LIN      83
0B6AH LIN      84
0B88H LIN      85
0B8FH LIN      86
0B96H LIN      87
0B99H LIN      88
0B9FH LIN      89
0BB6H LIN      90
0BB9H LIN      91
0BBFH LIN      92
0BD2H LIN      93
0BD5H LIN      94
0BDBH LIN      95
0BF2H LIN      96
0BF5H LIN      97
0BFBH LIN      98
0C12H LIN      99
0C15H LIN     100
0C1BH LIN     101
0C32H LIN     102
0C35H LIN     103
0C3BH LIN     104
0C52H LIN     105
0C55H LIN     106
0C5BH LIN     107
0C72H LIN     108
0C75H LIN     109
0C7BH LIN     110
0C92H LIN     111
0C95H LIN     112
0C9BH LIN     113
0CB2H LIN     114
0CB5H LIN     115
0CBBH LIN     116
0CD2H LIN     117
0CD5H LIN     118
0CDBH LIN     119
0CF2H LIN     120
0CF5H LIN     121
0CFBH LIN     122
0D12H LIN     123
0D15H LIN     124
0D1BH LIN     125
0D2EH LIN     126
0D31H LIN     127
0D37H LIN     128
0D4FH LIN     129
0D54H LIN     130
0D7CH LIN     131
0D84H LIN     132
0D8FH LIN     133
0D96H LIN     134
0D9DH LIN     135
0DA2H LIN     136
0DA9H LIN     137
0DAEH LIN     138
0DB4H LIN     139
0DB9H LIN     140
0DBEH LIN     141
0DC4H LIN     142
0DC7H LIN     143
0DCDH LIN     144
0D[illegible]H LIN     145
```

```
0DD6H LIN   [illegible]
0DD6H LIN    147
0DDDH LIN    148
0DDEH LIN    149
      MOD   FINALMODULE
391FH SYM   MEMORY
38DBH SYM   W
0DDFH SYM   FAST
0E09H SYM   GOOD
0E22H SYM   FAIR
0E48H SYM   POOR
38DCH SYM   TIMECREDIT
38DDH SYM   N
0E7EH SYM   COMMENT
0ED5H SYM   HX2AS
38DEH SYM   HEXADR
38E0H SYM   DECADR
38E2H SYM   N
38E3H SYM   M
0F62H SYM   COMPOSITE
0E66H SYM   COMP
38E4H SYM   OVERALL
38E6H SYM   DECNUM
0E7EH LIN      9
0E7EH LIN     10
0E89H LIN     12
0E8FH LIN     13
0E94H LIN     14
0E97H LIN     15
0EA2H LIN     17
0EA8H LIN     18
0EADH LIN     19
0EB0H LIN     20
0EBBH LIN     22
0EC1H LIN     23
0EC6H LIN     24
0EC9H LIN     26
0ECFH LIN     27
0ED4H LIN     28
0ED4H LIN     29
0ED5H LIN     30
0EDFH LIN     32
0EEDH LIN     33
0EF5H LIN     34
0F12H LIN     35
0F24H LIN     36
0F2BH LIN     37
0F30H LIN     38
0F4EH LIN     39
0F5AH LIN     40
0F5EH LIN     41
0F61H LIN     42
0F62H LIN     43
0F62H LIN     45
0FBBH LIN     46
0FC1H LIN     47
0FCDH LIN     49
0FD6H LIN     50
0FE4H LIN     51
0FF1H LIN     52
0FF8H LIN     53
0FF8H LIN     54
0FFDH LIN     55
 002H LIN     56
 007H LIN     57
      MOD   INTERRUPT7
```

```
1FH SYM   MEMORY
008H SYM   INTERRUPTROUTINE
1008H LIN       3
100 H LIN       4
1011H LIN       5
1015H LIN       6

MEMORY MAP OF MODULE UIWT
READ FROM FILE :F1:UIWT TMP
WRITTEN TO FILE :F1:UIWT
MODULE START ADDRESS 0001H

START    STOP LENGTH REL NAME

   0H      0H      1H  A   ABSOLUTE
   1H  10AFH   10AFH  A   ABSOLUTE
13F H  13FEH      3H  A   ABSOLUTE
```

```
ISIS-II IXREF, V1.1
INVOKED BY:
-IXREF F1:*.IXI TITLE('UIWT VERSION 1 2 INTER-MODULE CROSS-REFERENCE') &
PRINT(:F1:UIWT REF)

INTER-MODULE CROSS-REFERENCE LISTING
------------------------------------

 NAME . . . . . . ATTRIBUTES;  MODULE NAMES
 --------------------------------------------

 ADDER . . . .    STRUCTURE(5);  RIFLEDATAMODULE  RESULTSMODULE
 AVGTIME .        ADDRESS;  RESULTSMODULE  FINALMODULE
 BITDUMP . .      PROCEDURE;  CONSOLEMODULE  STARTUPMODULE
 CIN . . . .      PROCEDURE BYTE;  CONSOLEMODULE  TESTPROCMODULE  STARTUPMODULE
 CLOCKREAD .      PROCEDURE ADDRESS;  TIMERMODULE  RIFLEDATAMODULE  TESTPROCMODULE  MAINUIWTMODULE
 COMMENT . .      PROCEDURE;  FINALMODULE  RESULTSMODULE
 COMPOSITE .      PROCEDURE;  FINALMODULE  RESULTSMODULE
 COUT . . .       PROCEDURE;  CONSOLEMODULE  RIFLEDATAMODULE  TESTPROCMODULE  MAINUIWTMODULE  RESULTSMODULE
                    STARTUPMODULE  FINALMODULE
 DATE . . . . .   BYTE(12);  STARTUPMODULE  RESULTSMODULE
 DECIMAL . .      BYTE(3);  RESULTSMODULE  CONSOLEMODULE  STARTUPMODULE
 DELTATIME .      ADDRESS;  RIFLEDATAMODULE  MAINUIWTMODULE
 DONE .           PROCEDURE;  TESTPROCMODULE  TESTMODULE
 FAIL .           PROCEDURE;  TESTPROCMODULE
 FILE             BYTE;  RIFLEDATAMODULE  RESULTSMODULE  STARTUPMODULE  FINALMODULE
 FIRSTSHOT . .    BYTE(5);  RIFLEDATAMODULE  MAINUIWTMODULE  STARTUPMODULE
 FPTR .           BYTE;  RIFLEDATAMODULE
 GETRIFLEDATA .   PROCEDURE;  RIFLEDATAMODULE  MAINUIWTMODULE
 GREETING         PROCEDURE;  CONSOLEMODULE  MAINUIWTMODULE
 HISTORY . .      BYTE(5);  STARTUPMODULE  RIFLEDATAMODULE
 H2AS             PROCEDURE;  FINALMODULE
 IDFLAG           BYTE;  STARTUPMODULE  RESULTSMODULE
 IDNUMBER . .     BYTE(7);  STARTUPMODULE  RESULTSMODULE
 INTERRUPTROUTINE PROCEDURE;  INTERRUPT7  STARTUPMODULE
 IOTEST . . .     PROCEDURE;  TESTPROCMODULE  TESTMODULE
 LSTIMEBYTE . . . BYTE;  TIMERMODULE
 MSTIMEBYTE .     BYTE;  TIMERMODULE
 NAME . . .       STRUCTURE(5);  STARTUPMODULE  RESULTSMODULE
 NEARMISSES .     BYTE;  RESULTSMODULE  FINALMODULE
 PORTSET .        PROCEDURE;  STARTUPMODULE  TESTPROCMODULE
 PRESENTRESULTS   PROCEDURE;  RESULTSMODULE  MAINUIWTMODULE
 PRINT            PROCEDURE;  CONSOLEMODULE  TESTPROCMODULE  RESULTSMODULE  STARTUPMODULE  FINALMODULE
 PRINTNUM .       PROCEDURE;  CONSOLEMODULE  TESTPROCMODULE  RESULTSMODULE
 RAMTST .         PROCEDURE;  ** UNRESOLVED **  TESTMODULE
 REALGON . .      BYTE;  MAINUIWTMODULE  STARTUPMODULE
 RIFLE            BYTE;  RIFLEDATAMODULE  RESULTSMODULE  FINALMODULE
 RIFLESHOT .      PROCEDURE BYTE;  RIFLEDATAMODULE  MAINUIWTMODULE
 ROMTST .         PROCEDURE;  ** UNRESOLVED **  TESTMODULE
 SACTIM .         PROCEDURE;  ** UNRESOLVED **  TESTPROCMODULE
 SCORE            STRUCTURE(5);  RIFLEDATAMODULE  RESULTSMODULE  STARTUPMODULE  FINALMODULE
 SETDATA          PROCEDURE;  STARTUPMODULE  RIFLEDATAMODULE  MAINUIWTMODULE
 SHOTFLAG .       BYTE;  RIFLEDATAMODULE  STARTUPMODULE
 SHOWWORST        PROCEDURE;  RIFLEDATAMODULE  MAINUIWTMODULE
 SPEED            STRUCTURE(5)  RIFLEDATAMODULE  RESULTSMODULE  STARTUPMODULE  FINALMODULE
```

```
STARTUP. . . .    PROCEDURE;  STARTUPMODULE  MAINUINTMODULE
SUMSHOTS . . .    BYTE;  RESULTSMODULE  FINALMODULE
TARGETAVAILABLE   PROCEDURE BYTE;  RIFLEDATAMODULE  MAINUINTMODULE
TARGETDOWNTIME .  ADDRESS;  MAINUINTMODULE
TARGETEXPECTED .  BYTE;  MAINUINTMODULE
TARGETTIME . . .  ADDRESS;  MAINUINTMODULE  RIFLEDATAMODULE
TEST . . . . .    PROCEDURE;  TESTMODULE  MAINUINTMODULE
TFLAG . . . . .   BYTE;  MAINUINTMODULE  RIFLEDATAMODULE  STARTUPMODULE
TIME . . . .      ADDRESS;  TIMERMODULE
TIMERSTART . . .  PROCEDURE;  TIMERMODULE  TESTPROCMODULE  MAINUINTMODULE
TIMERTEST. . .    PROCEDURE;  TESTPROCMODULE  TESTMODULE
TRAIN . . . . .   BYTE;  MAINUINTMODULE  STARTUPMODULE  INTERRUPT7
TSTCHECK . . . .  BYTE;  TESTPROCMODULE  MAINUINTMODULE
TTYRES . . . .    PROCEDURE;  CONSOLEMODULE  TESTPROCMODULE  RESULTSMODULE
TTYSET . . . . .  PROCEDURE;  CONSOLEMODULE  TESTPROCMODULE  STARTUPMODULE
TTYTIMER . . .    PROCEDURE;  TIMERMODULE  TESTPROCMODULE  CONSOLEMODULE
TURKEY . . . . .  BYTE;  MAINUINTMODULE  RIFLEDATAMODULE  STARTUPMODULE
TXRDY . . . .     PROCEDURE;  CONSOLEMODULE  TESTPROCMODULE  MAINUINTMODULE
UPISTROBE . . .   PROCEDURE;  RIFLEDATAMODULE  TESTPROCMODULE  STARTUPMODULE
USARTTEST. . .    PROCEDURE;  TESTPROCMODULE  TESTMODULE
VOTRAXSET . . .   PROCEDURE;  CONSOLEMODULE  TESTPROCMODULE
VOTRAXTIMER       PROCEDURE;  TIMERMODULE  TESTPROCMODULE  CONSOLEMODULE
VOTRES . . . .    PROCEDURE;  CONSOLEMODULE  TESTPROCMODULE  MAINUINTMODULE
WHOFAILEDTOSHOOT  PROCEDURE;  RIFLEDATAMODULE  MAINUINTMODULE
```

MODULE DIRECTORY

MODULE NAME	FILE NAME	DISKETTE NAME
CONSOLEMODULE	CONSOL.PLM	UINT.TST
FINALMODULE . .	FINAL.PLM	UINT1.3
INTERRUPT7 .	INTER.PLM	UINT1.3
MAINUINTMODULE .	MAINUI.PLM	UINT1.2
RESULTSMODULE.	RESULT.PLM	UINT1.3
RIFLEDATAMODULE	RIFLE.PLM	UINT1.3
STARTUPMODULE.	START.PLM	UINT1.3
TESTMODULE . . .	TESTER.PLM	UINT.TST
TESTPROCMODULE	TSTPRC.PLM	UINT.TST
TIMERMODULE .	TIMER.PLM	UINT.TST

```
ISIS-II PL/M-80 V3.1 COMPILATION OF MODULE MAINUIWTMODULE
OBJECT MODULE PLACED IN :F1:MAINUI.OBJ
COMPILER INVOKED BY:  PLM80 :F1:MAINUI.PLM IXREF DEBUG DATE (1 FEB 79)


                /* THIS PROGRAM WAS WRITEN BY H.C. TOWLE IN THE WINTER AND SPRING OF 1978 */
                /*  IT ASSUMES THE SYSTEM HAS BEEN RESET PRIOR TO RUNNING */
                /* THIS MODIFICATION, WHICH RESULTS IN A CHANGE TO UIWT VERSION 1.2
                   RESULTS FROM THE REQUIREMENT TO SHOW THE WORST SHOOTER  */

   1            MAIN$UIWT$MODULE:
                  DO;


   2   1        SHOW$WORST: PROCEDURE EXTERNAL;
   3   2         END SHOW$WORST;

   4   1        DECLARE CLEAR$ACCUMULATOR BYTE A  (0) DATA(0AFH); /* AFH- EXCLUSIVE OR
                                          ACCUMULATOR WITH ITSELF*/
   5   1        TXRDY: PROCEDURE EXTERNAL;    /* CHECKS USART TRANSMIT BUFFER FOR "EMPTY" */
   6   2         END TXRDY;

   7   1        VOTRES: PROCEDURE EXTERNAL;  /* VOTRAX RESET. SEE CONSOL MODULE */
   8   2         END VOTRES;

   9   1        COUT: PROCEDURE (ITEM) EXTERNAL;  /* SENDS A BIT OUT THROUGH USART */
  10   2         DECLARE ITEM BYTE;
  11   2         END COUT;

  12   1        DECLARE USART$CONTROL LITERALLY '0EDH',  /* ADDRESS OF USART CONTROL P 3-32 */
                   USART$RESET LITERALLY '40H';          /* RETURNS 8251 TO MODE INST  FORMAT
                                                            REF  PAGE 3-13 */

  13   1            START$UP: PROCEDURE EXTERNAL;     /* SET I/O FOR RIFLE ETC. */
  14   2            END;

  15   1            TARGET$AVAILABLE: PROCEDURE BYTE EXTERNAL; /* CHECKS FOR AN IR SPOT
                                     IT WILL RETURN 1 IF IR SPOT IS FOUND. */
  16   2            END;

  17   1            TIMER$START: PROCEDURE EXTERNAL;  /* START 8253 REGISTERS */
  18   2            END;

  19   1            CLOCK$READ: PROCEDURE ADDRESS EXTERNAL; /* READS CLOCK FOR TARGET & SHOTS */
  20   2            END;

  21   1            RIFLE$SHOT: PROCEDURE BYTE EXTERNAL;   /* WAITS FOR ANY RIFLE SHOT */
  22   2            END;

  23   1            GET$RIFLE$DATA: PROCEDURE EXTERNAL;   /* READ & RECORD INPUT BYTE */
  24   2            END;

  25   1           SET$DATA: PROCEDURE (POINTER, LENGTH, VALUE) EXTERNAL;
  26   2            DECLARE POINTER ADDRESS, (LENGTH, VALUE) BYTE;
  27   2            END SET$DATA;
```

```
28  1          PRESENT$RESULTS: PROCEDURE EXTERNAL;   /* OUTPUTS DATA TO CONSOLE */
29  2          END;

30  1      DECLARE TSTCHECK BYTE EXTERNAL;

31  1      TEST: PROCEDURE EXTERNAL;
32  2        END TEST;

33  1        DECLARE FOREVER LITERALLY 'WHILE 1';
34  1          DECLARE COUNTER$SET LITERALLY '0EA5FH';
35  1          DECLARE (TRAINING, JK) BYTE;
36  1          DECLARE TRAIN BYTE PUBLIC AT (.TRAINING);
37  1          WHO$FAILED$TO$SHOOT  PROCEDURE EXTERNAL;  /* IDENTIFIES WHICH RIFLE MISSED
                                                        A  TARGET SHOT OPPORTUNITY */
38  2          END;
39  1          GREETING: PROCEDURE EXTERNAL;   /* PRINTS GREETING TO CONSOLE */
40  2          END;

41  1      TURKEY$TEST: PROCEDURE;  /* CHECKS FOR A 1 SECOND TIME ELAPSE SINCE TARGET DOWN */
42  2         IF TARGET$DOWN$TIME >= CLOCK$READ THEN
43  2         DELTA$TIME = TARGET$DOWN$TIME - CLOCK$READ;
           ELSE
44  2         DELTA$TIME = 1 + COUNTER$SET + TARGET$DOWN$TIME - CLOCK$READ;
45  2         IF DELTA$TIME > 200 THEN
46  2         TURKEY = 1;
47  2         ELSE TURKEY = 0;
48  2         END TURKEY$TEST;

49  1          DECLARE DELTA$TIME ADDRESS EXTERNAL;
50  1          DECLARE FIRST$SHOT(5) BYTE EXTERNAL;
51  1          DECLARE TARGET$DOWN$TIME ADDRESS PUBLIC;
52  1          DECLARE (TARGET$EXPECTED, TFLAG, REAL$GONE) BYTE PUBLIC;
53  1          DECLARE TURKEY BYTE PUBLIC;
54  1          DECLARE TARGET$TIME ADDRESS PUBLIC;

       /*   END OF DECLARATIONS */

       /*********************    PROGRAM STARTS    *********************/


55  1      TEST$BOARD$CHECK: DO;
56  2        IF TSTCHECK THEN /* IF ROM EXTENDER BOARD IS NOT PRESENT, THE 80/20 TIMES
                               OUT AND WILL READ 00 INTO THE ACCUMULATOR */
57  2          CALL TEST;  /*PERFORM 80/20 BOARD CHECK*/

58  2      END TEST$BOARD$CHECK;

59  1      UINT$PROGRAM: DO FOREVER

60  2      INITIALIZE
        CALL TIMER$START;

61  2       CALL START$UP;

62  2       CALL GREETING;

63  2       CALL TXRDY;  /* INSURE  "GREETING" HAS BEEN COMPLETED */
```

```
64   2      CALL VOTRES; /* SWITCH TO VOTRAX LINE & CHANGE TO 9600 BAUD */

65   2      TARGET$DOWN$TIME = CLOCK$READ + 200; /* FOR TURKEY TEST */

66   2     SESSION:
              DO WHILE TRAINING; /* WE WILL END WITH AN "ESCAPE" FROM CONSOLE */
67   3      IF TARGET$AVAILABLE OR RIFLE$SHOT THEN
68   3     ACTION: DO;    /* EITHER A RIFLE SHOT OR A TARGET AVAILABLE */
69   4           IF TARGET$AVAILABLE THEN
70   4     GOT$ONE: DO;
71   5       IF NOT TFLAG THEN
72   5     NEW$ONE: DO;      /* A NEW TARGET HAS APPEARED */
73   6               TARGET$TIME = CLOCK$READ;
74   6               REAL$GONE = 0;
75   6               TFLAG=1;
76   6               TURKEY = 0;
77   6               END NEW$ONE;
78   5     IF RIFLE$SHOT THEN
79   5     GOOD$DATA: CALL GET$RIFLE$DATA;
80   5               END GOT$ONE;
             ELSE   /* ELSE THERE IS NO TARGET, BUT A SHOT WAS FIRED */
81   4     NO$TARGET  DO;
82   5      CALL TURKEY$TEST;
83   5      CALL GET$RIFLE$DATA;
84   5           END NO$TARGET;
85   4          END ACTION;
            ELSE    /* ELSE THERE IS NEITHER A TARGET NOR SHOT */
86         NO$ACTION: DO;
87   4        IF TFLAG THEN  /* THAT IS, THERE WAS A TARGET ON LAST PASS */
88   4     TGONE: DO;
89   5         TARGET$DOWN$TIME = CLOCK$READ;
90   5         TFLAG = 0;
91   5           END TGONE;
92   4        IF NOT REAL$GONE THEN
93   4     WAIT$ONE: DO;
94   5           CALL TURKEY$TEST;   /* WE WILL HOLD REAL$GONE=0 FOR ONE SECOND */
95   5           IF TURKEY THEN /* WE SCORE "TARGET IGNORED" ONLY IF REAL$GONE=1 */
96   5     RECORD$GONE: DO;
97   6               REAL$GONE = 1;
98   6               CALL WHO$FAILED$TO$SHOOT;
99   6               CALL SET$DATA(FIRST$SHOT,5,1); /* NEXT SHOT AT A TARGET WILL BE TIMED */
100  6               CALL SHOW$WORST;
101  6               END RECORD$GONE;
102  5             END WAIT$ONE;
103  4        END NO$ACTION;
104  3       END SESSION;

105  2     ENDING

            CALL PRESENT$RESULTS;

107  2      CALL TXRDY;

108  2      OUTPUT(USART$CONTROL)=USART$RESET;

109  2      END UIMT$PROGRAM;
```

```
 109   1       END MAIN$UINT$MODULE;


MODULE INFORMATION:

     CODE AREA SIZE     = 0103H    259D
     VARIABLE AREA SIZE = 000AH     10D
     MAXIMUM STACK SIZE = 0006H      6D
     167 LINES READ
     0 PROGRAM ERROR(S)

END OF PL/M-80 COMPILATION
```

```
ISIS-II PL/M-80 V3.1 COMPILATION OF MODULE STARTUPMODULE
OBJECT MODULE PLACED IN :F1:START.OBJ
COMPILER INVOKED BY:  PLM80 :F1:START.PLM IXREF DEBUG DATE (25 JUN 79)



              $NOINTVECTOR

   1          START$UP$MODULE: DO;

   2   1      BIT$DUMP: PROCEDURE EXTERNAL;    /* IN CONSOLE$MODULE */
   3   2        END BIT$DUMP;

   4   1       DECLARE INTERRUPT7 LITERALLY '13FCH',
                      CALL$IT LITERALLY '0C3H';

   5   1       DECLARE INTERRUPT$CALL STRUCTURE (JUMP BYTE, WHERE$TO ADDRESS) AT (INTERRUPT7)
                 DATA (CALL$IT,  INTERRUPT$ROUTINE);

   6   1      DECLARE LIT LITERALLY 'LITERALLY',

               RESET$8212 LIT '0F8H',
               ENABLE$9311 LIT '10H',
               PORT3 LIT '0E6H',
               PORT6 LIT '0EAH',

               GROUP1 LIT '0E7H',     /* 8255 CONTROL  REF. PAGE 3-68 OF 80/20 MANUAL */
               WORD1 LIT '92H'     /* PORTS 1 & 2 INPUT, 3 OUTPUT ALL MODE 0  PAGE 4-13 --- */
               GROUP2 LIT '0EBH',        /* PAGE 3-68 */
               WORD2 LIT '80H'        /* PORTS 4,5 & 6 ALL OUTPUTS MODE 0 */
               USART$CONTROL LIT '0EDH',        /* PAGE 3-48 */
               USART$RESET LIT '40H',       /* INTERNAL RESET  PAGE 3-43 */
               MODE$SET LIT '0CEH',    /* SETS 2 STOP BITS, 8 BITS, 16X  PAGE 3-38,-41 & 4-48 */
                                     * USE 4EH FOR 1 STOP BIT, 8 BIT WORD & 64X */
               COMMAND$WORD LIT '27H'        /* SETS TRANSMIT/RECEIVER READY,
                               DATA TERMINAL READY, REQUEST TO SEND */
                           /* SEE PAGE 3-43 AND STEP 48 OF MDS MONITOR SHADOW PROM */
   7   1       DECLARE DECIMAL(3) BYTE EXTERNAL;
   8          DECLARE HISTORY(5) BYTE PUBLIC;    /* THIS WILL
                         IDENTIFY WHICH RIFLE WAS SHOT AT A PARTICULAR TARGET */
   9          DECLARE SCORE(5) STRUCTURE (MISS BYTE, HIT BYTE, LOW BYTE, LOW$RIGHT BYTE,
                  RIGHT BYTE, HIGH$RIGHT BYTE, HIGH BYTE, HIGH$LEFT BYTE,
                  LEFT BYTE, LOW$LEFT BYTE, ERROR BYTE, TURKEY BYTE,
                  TARGET$IGNORED BYTE) EXTERNAL;
  10           DECLARE (SHOT$FLAG, TURKEY, FILE, TFLAG, REAL$GONE) BYTE EXTERNAL,
                 FIRST$SHOT(5) BYTE EXTERNAL,
                 SPEED(5) STRUCTURE(SHOTS BYTE, TIME$SUM ADDRESS) EXTERNAL;
  11   1         DECLARE TRAIN BYTE EXTERNAL;
  12   1         DECLARE ADICW1 LITERALLY '0D3H',   /* REF PAGE 3-100 */
                        ADICW2 LITERALLY '0D9H';
  13             DECLARE OCW1 LITERALLY '7FH'


  14          DECLARE CRLF LIT '0DH,0AH',
                  NAME (5) STRUCTURE (LETTER(9) BYTE) PUBLIC,
                  DATE (12) BYTE PUBLIC,
```

```
                    ID$NUMBER (7) BYTE PUBLIC,
                    PROMPT LIT '3EH',
                    WHEN (16) BYTE DATA(15,'TODAY''S DATE?',CRLF),
                    UINT$ID (21) BYTE DATA (20, UINT/SWAT VER. 1.3',CRLF), /* CHANGED 6/25/79 */
                          /* TIMES FOR "FAST", "SLOW", ETC IN "FINAL.PLM" WERE INCREASED */
                          /* AT AL MARSHALL'S INSTRUCTIONS.  A CHANGE IS ALSO BEING MADE */
                          /* IN THE "SHOW$WORST" PROCEDURE IN RIFLE.PLM TO AVOID THE     */
                          /* PROBLEM WHERE ONLY FOUR RIFLES ARE SHOOTING ==> RIFLE #5 IS */
                          /* THE WORST BECAUSE OF ALL THE TARGET IGNOREDS & THERE IS NO */
                          /* RIFLE #5 "WORST-RIFLE" LIGHT. */

                    IDENT (19) BYTE DATA (18,'EXERCISE NUMBER?',CRLF),
                    QUERY (22) BYTE DATA (21,'WANT ID? YES OR NO.',CRLF),
                    TRAINEES (26) BYTE DATA (25,'ENTER NAMES OF TRAINEES',CRLF),
                    ON$RIFLE (10) BYTE DATA (9,' ON RIFLE '),
                    (X,I,J,K,JK) BYTE,
                    ID$FLAG BYTE PUBLIC;


  15   1       TTY$SET: PROCEDURE EXTERNAL;
  16   2        END TTY$SET; /* USED ONLY WHEN USART IS IN RESET CONDITION */

  17   1      CIN: PROCEDURE BYTE EXTERNAL;
  18   2       END CIN;

  19   1      COUT: PROCEDURE (ITEM) EXTERNAL;
  20   2       DECLARE ITEM BYTE;
  21   2       END COUT;
  22   1      PORT$SET: PROCEDURE PUBLIC;
  23   2        OUTPUT(GROUP1)=WORD1; /*SET CONTROL WORD INTO GROUP 1 I/O PORTS */
  24   2        OUTPUT(GROUP2)=WORD2; /*SET CONTROL WORD INTO GROUP 2 I/O PORTS */
  25   2        END PORT$SET;

  26   1      PRINT: PROCEDURE(PTR) EXTERNAL;
  27   2       DECLARE PTR ADDRESS;
  28   2       END PRINT;

  29   1      SET$DATA: PROCEDURE(POINTER,LENGTH,VALUE) PUBLIC;
  30   2        DECLARE (POINTER, FINAL) ADDRESS,
                 (LENGTH, VALUE, SET BASED POINTER) BYTE;
  31   2        FINAL = POINTER + LENGTH - 1;
  32   2       LOOP: DO WHILE POINTER <= FINAL;
  33   3         SET = VALUE;
  34   3         POINTER = POINTER+1;
  35   3         END LOOP;
  36   2        END SET$DATA;

  37   1      INTERRUPT$ROUTINE: PROCEDURE INTERRUPT 7 EXTERNAL;
  38   2         END INTERRUPT$ROUTINE;

  39   1      UPI$STROBE: PROCEDURE EXTERNAL;
  40   2        END UPI$STROBE;

  41   1      SIMULATE$RIFLES: PROCEDURE;
  42   2        OUTPUT(PORT6)=0AH;  /* TELL UPI-41 TO SIMULATE RIFLE DATA */
  43   2        CALL UPI$STROBE;
  44   2        END SIMULATE$RIFLES;
```

```
45  1     DECLARE CTRLT LIT '14H', RUN$TYPE BYTE;

          /**************** END OF DECLARATIONS *****************/

46  1      START$UP: PROCEDURE PUBLIC;

47  2      CALL SET$DATA(.SCOPE,65,0);
48  2      CALL SET$DATA(.HISTORY,5,0);
49         CALL SET$DATA(.FIRST$SHOT,5,1);
50         CALL SET$DATA(.SPEED,15,0);
51         CALL SET$DATA(.DECIMAL,3,0);
52         TURKEY = 0;
53  2      TRAIN = 1;
54  2      TFLAG = 0;
55  2      SHOT$FLAG = 0;
56  2      FILE = 4;  /* WHO$SHOT FIRST INCREMENTS FILE, MODS (DIVIDES) BY 5,
                      I.E. 5/5=1 WITH REMAINDER = 0  NOW, RIFLE=FILE+1,
                      SO WE START WITH RIFLE #1 !!! */

57  2      REAL$GONE = 1;  /* TARGET HAS NOT BEEN AVAILABLE FOR OVER 1 SEC  */

58  2       CALL PORT$SET;

59  2       OUTPUT(PORT3) = NOT RESET$8212;     /* WILL CLEAR ALL 8212 DATA
                                                LATCHES FOLLOWING STROBE */
60  2       OUTPUT(PORT6) = ENABLE$9:11;    /* THE LEADING EDGE OF THE STROBE */
61  2       OUTPUT(PORT6) = 0;              /* THE TRAILING EDGE   */

62  2      DO JK = 9 TO 13;     /* CLEARS THE JK FF DATA LATCHES */
63  3       OUTPUT(PORT3) = NOT JK AND 0FH;
64  3       OUTPUT(PORT6) = ENABLE$9:11;
65  3       OUTPUT(PORT6) = 0;
66  3       END;


67  2     DISABLE;
68  2       CALL TTY$SET;

69  2     SETINT: OUTPUT(ADICW1)=(LOW(INTERRUPT7) AND 0E0H) + 1FH;
70  2           OUTPUT(ADICW2)=HIGH(INTERRUPT7);
71  2           OUTPUT(ADICW2)=0CWH1;  /* MASK ALL BUT INTERRUPT 7 */

          /* WE NOW OBTAIN IDENTIFICATION DATA FOR THE SESSION, IF NEEDED */

72  2     CALL COUT(0DH);      /* CR */
73  2     CALL COUT(0AH);      /* LF */
74  2     CALL COUT(0AH);

75  2     CALL PRINT(.UINT$ID);
76  2     CALL COUT(0AH);
77  2     CALL PRINT(.QUERY);
78  2     CALL OUTPUT (PROMPT);
79  2     X=CIN;
80  2      RUN$TYPE = X;       /* SAVE INPUT FOR IDENTIFICATION OF CONTROL T */
81  2     CALL COUT(X);
```

```
 82  2        CALL COUT(0DH);
 83  2        CALL COUT(0AH);  /* CR,LF */
 84  2        ID$FLAG=0;       /* CONTROL FOR ID PRINT-OUT AT END OF SESSION */

 85  2        IF X = 'Y' THEN
 86  2        GET$ID: DO;
 87  3         ID$FLAG=1;

 88  3         CLR$DATE: CALL SET$DATA(.DATE,12,0DH); /* CLEARS "DATE" */

 89  3         CALL PRINT(.WHEN);
 90  3         CALL COUT(PROMPT);

 91  3         DATE(0)=11;

 92  3        GET$DATE:
               DO I=1 TO 9;
 93  4          X=CIN;
 94  4          IF X=0DH THEN I=9;
 96  4          CALL COUT(X);
 97  4          DATE(I) = X;
 98  4         END GET$DATE;

 99  3         CALL COUT(0DH);
100  3         DATE(11) = 0AH;  /* LF */
101  3         CALL COUT(0AH);

102  3        CALL SET$DATA( ID$NUMBER,7,0DH);    /* FILLS "ID NUMBER" WITH CR */

103  3        CALL PRINT(.IDENT);
104  3        CALL COUT(PROMPT);

105  3        CALL BIT$DUMP;  /* CLEAN OUT USART INPUT BUFFER */

106  3         ID$NUMBER(0)=6;

107  3        GET$ID$NUMBER: DO I=1 TO 4;      /* A 4 PLACE "ID" */
108  4         X=CIN;
109  4         IF X=0DH THEN I=4;
111  4          CALL COUT(X);
112  4          ID$NUMBER(I)=X;
113  4         END GET$ID$NUMBER;

114  3         CALL COUT(0DH);
115  3         ID$NUMBER(6)=0AH;
116  3         CALL COUT(0AH);


117  3       CALL SET$DATA(.NAME,45,0DH); /* FILLS NAME MATRIX WITH CR */

118  3        CALL PRINT(.TRAINEES);

119  3       GET$NAMES:
              DO I=0 TO 4;                      /* FOR FIVE TRAINEES */

120  4        CALL PRINT(.ONE$RIFLE);
121  4        CALL COUT(31H+I);
```

```
122   4        CALL COUT(0DH);
123   4        CALL COUT(0AH);
124   4        CALL COUT(PROMPT);

125   4        CALL BIT$DUMP;

126   4        NAME(I).LETTER(0)=0;

127   4       ONE$NAME:
                DO J=1 TO 6;            /* GETS NAMES UP TO 6 LETTERS LONG */
128   5         X=CIN;
129   5         IF X=0DH THEN J=6;
131   5           NAME(I).LETTER(J)=X;
132   5           CALL COUT(X);
133   5         END ONE$NAME;
134   4         CALL COUT(0DH);             /* CR */
135   4         NAME(I).LETTER(8) = 0AH;    /* LF */
136   4         CALL COUT (0AH);
137   4        END GET$NAMES;
138   3       END GET$ID;

139   2       IF RUN$TYPE = CTRLT THEN
140   2         CALL SIMULATE$RIFLES.

141   2           END START$UP;
142   1         END START$UP$MODULE;



MODULE INFORMATION:

     CODE AREA SIZE     = 033FH    831D
     VARIABLE AREA SIZE = 0052H     82D
     MAXIMUM STACK SIZE = 0004H      4D
     248 LINES READ
     0 PROGRAM ERROR(S)

END OF PL/M-80 COMPILATION
```

ISIS-II PL/M-80 V3.1 COMPILATION OF MODULE TIMERMODULE
OBJECT MODULE PLACED IN :F1:TIMER.OBJ
COMPILER INVOKED BY: PLM80 :F1:TIMER.PLM DEBUG IXREF DATE (23 OCT 78)

```
  1          TIMER$MODULE: DO;

             /* THIS MODULE SETS THE 8253 MODES AND READS REGISTERS.  NOTE THAT ALL
             THREE 8253 GATES MUST BE HIGH! ALL PAGE REFERENCES ARE TO THE 80/20
             REFERENCE MANUAL 98-317C */
  2   1      DECLARE LIT LITERALLY 'LITERALLY',
              COUNTER0 LIT '0DCH', COUNTER1 LIT '0DDH',
              COUNTER2 LIT '0DEH', CONTROL LIT '0DFH';     /* SEE PAGE 2-7 */
  3   1      DECLARE CNTR0MODE LIT '34H',  /* 2 BYTES, MODE 2 PAGE 3-76 */
              CNTR1MODE LIT '74H',         /* 2 BYTES, MODE 2 */
              CNTR2MODE LIT '0B6H';        /* 2 BYTES, MODE 3 */

             /*THE FOLLOWING 2-BYTE WORDS ARE THE "BAUD RATE FACTORS" TABLE 4-34 P 4-48 */

  4   1      DECLARE LOW0 LIT '0',     /* COUNTER 0 PERIOD IS 5 MILLESECONDS */
              HIGH0 LIT '15H',
              LOW1 LIT '5FH',          /* COUNTER 1 PERIOD IS 5 MINUTES */
              HIGH1 LIT '0EAH',     /* = 5 MIN * 60 (SEC/MIN) / 0.005 SEC -1 IN HEX */
                 /********SET UP FOR 300 BAUD *************/
              LOW2 LIT '0E0H',          /* COUNTER 2 FREQUENCY IS 4.8 KHZ  */
              HIGH2 LIT '00',  /* SEE PAGE 3-38, AND NOTE THAT THE 8251 IS SET FOR 16X */

              LOW$VOTRAX LIT '07H',
              HIGH$VOTRAX LIT '00H';  /* SETS VOTRAX OUTPUT TO 9600 BAUD */

  5   1      DECLARE TIME$LATCH LIT '40H',     /* A COUNTER 1 LATCH. PAGE 3-84. */
              (LS$TIME$BYTE, MS$TIME$BYTE) BYTE PUBLIC;
  6   1      DECLARE TIME ADDRESS PUBLIC;
  7   1      DECLARE LOW$TIME$BYTE BYTE AT (.TIME), HIGH$TIME$BYTE BYTE AT (.TIME + 1);

  8   1      TIMER$START: PROCEDURE PUBLIC;
  9   2       OUTPUT(CONTROL)=CNTR0MODE;     /* SET COUNTERS 0 & 1 MODES */
 10   2       OUTPUT(CONTROL)=CNTR1MODE;
 11   2       OUTPUT(COUNTER0)=LOW0;      /* INITIALIZE COUNTERS */
 12   2       OUTPUT(COUNTER0)=HIGH0;
 13   2       OUTPUT(COUNTER1)=LOW1;
 14   2       OUTPUT(COUNTER1)=HIGH1;
 15   2       END TIMER$START;

 16   1      TTY$TIMER: PROCEDURE PUBLIC;
 17   2       OUTPUT(CONTROL)=CNTR2MODE;
 18   2       OUTPUT(COUNTER2)=LOW2;      /* WORDS FOR 300 BAUD */
 19   2       OUTPUT(COUNTER2)=HIGH2;
 20   2       END TTY$TIMER;

 21   1      VOTRAX$TIMER: PROCEDURE PUBLIC;    /* SET VOTRAX TO 9600 BAUD */
 22   2       OUTPUT(CONTROL)=CNTR2MODE;
 23   2       OUTPUT(COUNTER2)=LOW$VOTRAX;
 24   2       OUTPUT(COUNTER2)=HIGH$VOTRAX;
 25   2       END VOTRAX$TIMER;
```

```
26   1      CLOCK$READ: PROCEDURE ADDRESS PUBLIC;  /* GETS THE CONTENTS OF COUNTER 1 */
27   2       OUTPUT(CONTROL)=TIME$LATCH;
28   2       LOW$TIME$BYTE=INPUT(COUNTER1);
29   2       HIGH$TIME$BYTE=INPUT(COUNTER1);
30   2       RETURN TIME;
31   2       END CLOCK$READ;

32   1      END TIMER$MODULE;


MODULE INFORMATION:

     CODE AREA SIZE     = 0045H     69D
     VARIABLE AREA SIZE = 0004H      4D
     MAXIMUM STACK SIZE = 0000H      0D
     59 LINES READ
     0 PROGRAM ERROR(S)

END OF PL/M-80 COMPILATION
```

```
ISIS-II PL/M-80 V3.1 COMPILATION OF MODULE RIFLEDATAMODULE
OBJECT MODULE PLACED IN :F1:RIFLE.OBJ
COMPILER INVOKED BY:  PLM80 :F1:RIFLE.PLM IXREF DEBUG DATE (25 JUN 79)


  1          RIFLE$DATA$MODULE: DO;

             /* INCLUDES VARIOUS PROCEDURES FOR RIFLE DATA I/O */

  2   1      DECLARE MESSAGE BYTE;

  3   1      COUT: PROCEDURE (ITEM) EXTERNAL;
  4   2       DECLARE ITEM BYTE;
  5   2       END COUT;


  6   1      SCORIT: PROCEDURE(SHOT$LOCATION,FILE);
  7   2             DECLARE (SHOT$LOCATION,FILE) BYTE;
  8   2             ADDER(FILE).J(SHOT$LOCATION)=ADDER(FILE).J(SHOT$LOCATION)+1;
  9   2             END SCORIT;

             /* DECODE TRANSLATES QUADRANT DATA INTO SHOT POSITION. NOTE THAT
                 ERRORS ARE TREATED A MISSES.  THUS A "HIGH-LOW" OR A "LEFT-RIGHT"
                 WHICH SHOULD NEVER OCCUR IS A MISS.  TO SCORE AS ERRORS CHANGE THE
                 SECOND AND THIRD 0 OF DECODE INTO "10" */
 10   1      DECLARE DECODE(16) BYTE DATA(0,2,4,3,6,0,5,4,8,9,0,2,7,8,6,1);

 11   1      CLOCK$READ: PROCEDURE ADDRESS EXTERNAL;
 12   2       END CLOCK$READ;

 13   1      SET$DATA: PROCEDURE(PTR,LENGTH,VALUE) EXTERNAL;
 14   2       DECLARE (LENGTH, VALUE)BYTE, PTR ADDRESS;
 15   2       END SET$DATA;

 16   1      DECLARE FIRST$SHOT(5) BYTE PUBLIC;
 17   1      DECLARE LIT LITERALLY 'LITERALLY',
              HIGH$WD LIT '0EH', LOW$WD LIT '1', RIGHT$WD LIT '2', LEFT$WD LIT '3',
              HIT$WD LIT '4', MISS$WD LIT '5', NO$WD LIT '6', TARGET$WD LIT '7',
              SOLDIER$WD LIT '8', YOU$WD LIT '9', A$WD LIT '0AH',
              WAS$WD LIT '0BH', MARINE$WD LIT '0CH', ENEMY$WD LIT '0DH',
              AVAILABLE$WD LIT '32', FROZE$WD LIT '0FH',
              PORT1 LIT '0E4H',  /* PAGE 3-62 OF 80/20 MANUAL */
              PORT2 LIT '0E5H',
              PORT3 LIT '0E6H',
              PORT4 LIT '0E8H',
              PORT6 LIT '0EAH',
              ENABLE1 LIT '10H';
 18   1      DECLARE COUNTER$SET LIT '0EA5FH';  /* INITIAL VALUE 5 MIN COUNTER */
 19   1      DECLARE HISTORY(5) BYTE EXTERNAL;
 20   1      DECLARE (TURKEY, TFLAG) BYTE EXTERNAL;
 21   1      DECLARE SCOPE(5) STRUCTURE(MISS BYTE, HIT BYTE, LOW BYTE, LOW$RIGHT BYTE,
                  RIGHT BYTE, HIGH$RIGHT BYTE, HIGH BYTE, HIGH$LEFT BYTE,
                  LEFT BYTE, LOW$LEFT BYTE, ERROR BYTE, TURKEY BYTE,
                  TARGET$IGNORED BYTE) PUBLIC;
             /* WE WILL USE "ADDER" TO COMPUTE TOTAL SHOTS */
 22   1      DECLARE ADDER(5) STRUCTURE ( J(13) BYTE) PUBLIC AT (.SCOPE);
```

```
23   1      DECLARE SPEED(5) STRUCTURE(SHOTS BYTE, TIME$SUM ADDRESS) PUBLIC;
24   1      DECLARE TOTAL$TIME ADDRESS;
25   1      DECLARE DELTA$TIME ADDRESS PUBLIC;
26   1      DECLARE (FILE,RIFLE,FPTR) BYTE PUBLIC;
27   1      DECLARE SHOT$FLAG BYTE PUBLIC;
28   1      DECLARE TARGET$TIME ADDRESS EXTERNAL;
29   1      DECLARE RIFLE$ID BYTE;
30   1      DECLARE CRT$STROBE LIT '00100000B';

31   1      UPI$STROBE: PROCEDURE PUBLIC;
32   2       OUTPUT(PORT3) = CRT$STROBE;
33   2       OUTPUT(PORT3) = 0;
34   2       END UPI$STROBE;

35   1      TARGET$AVAILABLE: PROCEDURE BYTE PUBLIC;  /* GIVES "TRUE" IF TARGET PRESENT */
36   2      DECLARE TARGET BYTE;
37   2      TARGET=INPUT(PORT2);
38   2       RETURN TARGET;  /* PORT 2 BIT NUMBER 0 WILL BE HIGH IF TARGET PRESENT */
39   2       END TARGET$AVAILABLE;

40   1      RIFLE$SHOT: PROCEDURE BYTE PUBLIC;  /* RETURNS "TRUE" IF SHOT FIRED */
41   2       SHOT$FLAG=INPUT(PORT1);   /* "SHOT$FLAG" IS TRUE WHEN SHOT FIRED! */
42   2       RETURN SHOT$FLAG;
43   2       END RIFLE$SHOT;

44   1      GET$RIFLE$DATA: PROCEDURE PUBLIC;
45   2       DECLARE SHOT$DATA BYTE;
46   2      UNRESOLVED: DO WHILE SHOT$FLAG:=INPUT(PORT1);
47   3       SHOT$DATA=0;     /* NEEDED TO ENTER FOLLOWING "WHO$SHOT" ROUTINE */
48   3      WHO$SHOT: DO WHILE NOT SHOT$DATA;
49   4       FILE = (FILE+1) MOD 5;  /* FILE 0 CONTAINS RIFLE NUMBER 1 DATA,
                                        FILE 1 ==> RIFLE #2, ETC. */
50   4       RIFLE=FILE+1;   /*"FILE" IS INTIALIZED ONLY ONCE. THUS
                                    WE START CHECKING WHERE WE LEFT OFF */
51   4       SHOT$DATA=SHR(SHOT$FLAG,RIFLE);
52   4       END WHO$SHOT;  /* "RIFLE" EQUALS SHOOTING RIFLE NUMBER */

53   3      RIFLE$ID = ROR(RIFLE,3);  /* GET RIFLE ID INTO HIGH ORDER BITS */

54   3       IF NOT TURKEY THEN
55   3      DO;
56   4        IF FIRST$SHOT(FILE) THEN
57   4      HOW$QUICK: DO;
58   5        IF TARGET$TIME >= CLOCK$READ THEN
59   5         DELTA$TIME = TARGET$TIME - CLOCK$READ;
          ELSE
60   5         DELTA$TIME = COUNTER$SET + 1 + TARGET$TIME - CLOCK$READ;
61   5       SPEED(FILE).TIME$SUM=SPEED(FILE).TIME$SUM + DELTA$TIME;
62   5       SPEED(FILE).SHOTS = SPEED(FILE).SHOTS + 1;
63   5       FIRST$SHOT(FILE) = 0;
64   5        END HOW$QUICK;
65   4      END;

66   3     HISTORY(FILE) = 1;

67   3     OUTPUT(PORT3)=NOT RIFLE AND 0FH; /* SETS 9311 ADDRESS OF /DS1 LINE # RIFLE */
68   3     OUTPUT(PORT3) = ENABLE1;  /* LATCHES SHOT$DATA FROM RIFLE ONTO BUS */
```

```
 69  3      SHOT$DATA=INPUT(PORT2);  /* READS QUADRANT DATA */

 70  3      OUTPUT(PORT6) = 0;   /* RETURNS /DS1 # RIFLE HIGH AND DROPS 8212 FROM BUS */

 71  3      OUTPUT(PORT3)=NOT(8H OR RIFLE) AND 0FH;   /* ADDRESSES 9311 /GOT DATA # RIFLE */
 72  3      OUTPUT(PORT6) = ENABLE1;
 73  3      OUTPUT(PORT6) = 0;

 74  3      CALL COUT(0FFH);        /* OUTPUT "SYN" MESSAGE TO VOTRAX */

 75  3      CALL COUT(0C0H + RIFLE);     /* RIFLE ADDRESSED */

 76  3      IF (NOT TURKEY) AND TFLAG THEN
 77  3      OK$DATA: DO;  /* ADD IN NEW SCORE DATA  ASSUME FOR PORT 2 THAT
                             BIT 1 = LOW, BIT 2 = RIGHT
                             BIT 3 = HIGH, BIT 4 = LEFT */

 78  4      CALL SCORIT(MESSAGE:=DECODE(SHR(SHOT$DATA,1) AND 0FH),RIFLE);

 79  4      OUTPUT(PORT6) = NOT(RIFLE$ID + MESSAGE) AND 11101111B;
 80  4      CALL UPI$STROBE;

 81  4      VOTRAX$MESSAGES: DO CASE MESSAGE;
 82  5      CALL COUT(MISS$WD);
 83  5      CALL COUT(HIT$WD);
 84  5      CALL COUT(LOW$WD);
 85  5      DO;
 86  6         CALL COUT(LOW$WD);
 87  6         CALL COUT(RIGHT$WD);
 88  6         END;
 89  5      CALL COUT(RIGHT$WD);
 90  5      DO;
 91  6         CALL COUT(HIGH$WD);
 92  6         CALL COUT(RIGHT$WD);
 93  6         END;
 94  5      CALL COUT(HIGH$WD);
 95  5      DO;
 96  6         CALL COUT(HIGH$WD);
 97  6         CALL COUT(LEFT$WD);
 98  6         END;
 99  5      CALL COUT(LEFT$WD);
100  5      DO;
101  6         CALL COUT(LOW$WD);
102  6         CALL COUT(LEFT$WD);
103  6         END;
104  5       END VOTRAX$MESSAGES;
105  4      END OK$DATA;

106         IF TURKEY THEN
107         DO;
108  4      TURKEY$DATA: SCORE(FILE).TURKEY = SCORE(FILE).TURKEY+1;
109  4       OUTPUT(PORT6) = NOT(RIFLE$ID + 0BH) AND 11101111B;
110  4       CALL UPI$STROBE;   /* SENDS TURKEY TO CONSOLE CRT */
111  4       CALL COUT(NO$WD);
112  4       CALL COUT(TARGE$WD);
```

```
113  4        END;

114  3       IF (NOT TFLAG) AND (NOT TURKEY) THEN
115  3       DO;
116  4        SCORE(FILE).MISS = SCORE(FILE).MISS + 1;
117  4        OUTPUT(PORT6) = NOT(RIFLE$ID + 0AH) AND 11101111B;
118  4        CALL UPI$STROBE;    /* SENDS "MISS- LATE" MESSAGE TO CONSOLE CRT */
119  4        CALL COUT(MISS$WD);
120  4        END;

121  3        CALL COUT(0FFH);       /* VOTRAX SIGN-OFF */

122  3        END UNRESOLVED;
123  2       END GET$RIFLE$DATA;

124  1       WHO$FAILED$TO$SHOOT: PROCEDURE PUBLIC;
125  2       DO FPTR=0 TO 4;
126  3        RIFLE$ID = ROR(FPTR+1,3);
127  3        IF HISTORY(FPTR)=0 THEN
128  3         DO;
129  4          SCORE(FPTR).TARGET$IGNORED=SCORE(FPTR).TARGET$IGNORED+1;
130  4          OUTPUT(PORT6) = NOT(RIFLE$ID + 0CH) AND 11101111B;
131  4          CALL UPI$STROBE;   /* SENDS TARGET IGNORED TO CONSOL CRT */
132  4          CALL COUT(0FFH);      /* VOTRAX "INT" MESSAGE */
133  4          CALL COUT(0C0H + FPTR);       /* ADDRESS RIFLE NOT SHOOTING */
134  4          CALL COUT(YOU$WD);
135  4          CALL COUT(FROZE$WD);
136  4          CALL COUT(0FFH);      /* END OF VOTRAX MESSAGE */
137  4          END;
138  3         END;
139  2        CALL SET$DATA(.HISTORY,5,0);
140  2       END WHO$FAILED$TO$SHOOT;

141  1       SHOW$WORST: PROCEDURE PUBLIC;
142  2        DECLARE BAD$WORD BYTE;
143  2        DECLARE BAD$NEWS(5) BYTE;
144  2        HOW$BAD: DO FPTR = 0 TO 4;
145  3        BAD$NEWS(FPTR) = 0;
146  3         IF SPEED(FPTR) SHOTS<>0 THEN  /* AVOIDS "WORST-SHOOTER" IF NO RIFLE AT FPTR */
147  3         BAD$NEWS(FPTR) = SCORE(FPTR).MISS + SCORE(FPTR).TURKEY +
                              SCORE(FPTR).TARGET$IGNORED;
148  3        END HOW$BAD;
149  2       BAD$WORD = 1;
150  2       RIFLE = 1;
151  2       HUNT$WORST: DO FPTR = 0 TO 3;
152  3        IF BAD$NEWS(FPTR+1) = BAD$NEWS(RIFLE-1) THEN
153  3         BAD$WORD = BAD$WORD OR ROL(80H, FPTR + 2));
154  3        IF BAD$NEWS(FPTR+1) > BAD$NEWS(RIFLE-1) THEN
155  3         DO;
156  4          RIFLE = FPTR + 2;
157  4          BAD$WORD = (BAD$WORD AND 0) OR ROL(80H,RIFLE);
158  4          END;
159  3        END HUNT$WORST;          /* RIFLE HAS VALUE OF WORST SHOOTER */
160  2       OUTPUT(PORT4) = BAD$WORD;
161  2       END SHOW$WORST;

162  1      END RIFLE$DATA$MODULE;
```

```
MODULE INFORMATION:

     CODE AREA SIZE     = 03B7H    951D
     VARIABLE AREA SIZE = 0069H    105D
     MAXIMUM STACK SIZE = 0004H      4D
     222 LINES READ
     0 PROGRAM ERROR(S)

END OF PL/M-80 COMPILATION
```

```
ISIS-II PL/M-80 V3.1 COMPILATION OF MODULE CONSOLEMODULE
OBJECT MODULE PLACED IN :F1:CONSOL.OBJ
COMPILER INVOKED BY  PLM80 :F1:CONSOL.PLM DEBUG IXREF DATE (12 OCT 78)


   1        CONSOLE$MODULE: DO;
            /* THIS MODULE CONTAINS CONSOLE I/O ROUTINES */

   2   1    DECLARE USART$DATA LITERALLY '0ECH',     /* PAGE 3-48 OF 80/20 MANUAL */
             USART$STATUS LITERALLY '0EDH',          /* PAGE 3-44 */
             ESC LITERALLY '1BH',                    /* ASCII "ESCAPE" */
             MASK LITERALLY '7FH',
             ZERO LITERALLY '30H',
             CR LITERALLY '0DH', LF LITERALLY '0AH',
             ENABLE$9311 LITERALLY '10H',
             PORT3 LITERALLY '0E6H'
             PORT6 LITERALLY '0EAH',
             TTY$LINE LITERALLY '08H',
             VOTRAX$LINE LITERALLY '09H',
             USART$CONTROL LITERALLY '0EDH',

            /*********THE SILENT 700 IS HEREAFTER DEFINED AS A TTY ************/
             TTY$MODE LITERALLY '0CEH',  /* 1 STOP BITS, 8 BIT, 16X, P. 3-38,41,4-48 */
             VOTRAX$MODE LITERALLY '4EH',  /* DITTO EXCEPT 1 STOP BIT */
             USART$COMMAND LITERALLY '27H'  /* DATA TERMINAL READY, ETC */
             USART$RESET LITERALLY '40H',
             HELLO (18) BYTE DATA (17, CR, LF,LF,LF, 'LET''S START', CR, LF);
   3   1    DECLARE DECIMAL(3) BYTE EXTERNAL;
   4   1    DECLARE (I,Y,GOS) BYTE;

   5   1    TTY$TIMER: PROCEDURE EXTERNAL;
   6   2     END;

   7   1    VOTRAX$TIMER: PROCEDURE EXTERNAL;
   8   2     END;

   9   1    TTY$SET: PROCEDURE PUBLIC;
  10   2      OUTPUT(PORT3) = TTY$LINE;  /* WILL DIRECT USART OUTPUT TO TTY */
  11   2      OUTPUT(PORT6) = ENABLE$9311;
  12   2      OUTPUT(PORT6) = 0;

  13   2      CALL TTY$TIMER;   /* SETS UP FOR 110 BAUD */

  14   2     OUTPUT(USART$CONTROL) = TTY$MODE;
  15   2     OUTPUT(USART$CONTROL) = USART$COMMAND;
  16   2      END TTY$SET;

  17   1    TTYRES: PROCEDURE PUBLIC;     /* TTY RESET */
  18   2     OUTPUT(USART$CONTROL) = USART$RESET;
  19   2     CALL TTY$SET;
  20   2     END TTYRES;

  21   1    VOTRAX$SET: PROCEDURE PUBLIC;
  22   2      OUTPUT(USART$CONTROL) = VOTRAX$MODE;
  23   2      OUTPUT(USART$CONTROL) = USART$COMMAND;
  24   2    END VOTRAX$SET;
```

```
25  1      VOTRES: PROCEDURE PUBLIC;    /* VOTRAX RESET */
26  2        OUTPUT(USART$CONTROL) = USART$RESET;
27  2        OUTPUT(PORT3) = VOTRAX$LINE;
28  2        OUTPUT(PORT6) = ENABLE$9311;
29  2        OUTPUT(PORT6) = 0;

30  2        CALL VOTRAX$TIME;
31  2        CALL VOTRAX$SET;

32  2        END VOTRES;

33  1      CIN: PROCEDURE BYTE PUBLIC;    /* GETS A BYTE FROM THE CONSOLE */
34  2      RXRDY: DO WHILE NOT SHR(INPUT(USART$STATUS),1);  /* I.E. WHILE INPUT BUFFER
                                                             IS NOT READY */
35  3        END RXRDY;
36  2      RETURN MASK AND INPUT(USART$DATA);
37  2        END CIN;

38  1      TXRDY: PROCEDURE PUBLIC;
39  2        DO WHILE NOT SHR(INPUT(USART$STATUS),2);
40  3         END;
41  2          END TXRDY;

42  1      COUT: PROCEDURE (ITEM) PUBLIC;           /* OUTPUTS "ITEM" */
43  2       DECLARE ITEM BYTE;
44  2        DO WHILE NOT(INPUT(USART$STATUS));
45  3           END;
46  2       OUTPUT(USART$DATA)=ITEM;
47  2        END COUT;

48  1      BIT$DUMP: PROCEDURE PUBLIC;
49  2        Y = INPUT(USART$DATA);      /* "Y" HERE IS A BIT-BUCKET */
50  2        END BIT$DUMP;

51  1      PRNTNUM: PROCEDURE PUBLIC;
52  2       GOS=0;
53  2       DO I=0 TO 2;
54  3       IF (Y:=DECIMAL(I)) <> ZERO THEN
55  3         GOS=1;
56  3       IF GOS THEN CALL COUT(Y);
58  3        END;
59  2       CALL COUT(CR);
60  2       CALL COUT(LF);
61  2       END PRNTNUM;

62  1      PRINT: PROCEDURE(POINTER) PUBLIC;
63  2       DECLARE (POINTER, FINAL) ADDRESS,
             CHAR BASED POINTER BYTE;
64  2       FINAL=POINTER+CHAR;             /* FIRST CHAR IS CHARACTER COUNT */
65  2      LOOP: DO WHILE POINTER < FINAL;
66  3       POINTER=POINTER+1;
67  3       CALL COUT(CHAR);
68  3        END LOOP;
69  2        END PRINT;

70  1      GREETING: PROCEDURE PUBLIC;
```

```
  71   2          CALL PRINT( HELL ));
  72   2          CALL BIT$DUMP;
  73   2          ENABLE;
  74   2          END GREETING;

  75   1        END CONSOLE$MODULE
```

```
MODULE INFORMATION:

     CODE AREA SIZE     = 010FH    271D
     VARIABLE AREA SIZE = 0000H      0D
     MAXIMUM STACK SIZE = 0004H      4D
     115 LINES READ
     0 PROGRAM ERROR(S)

END OF PL/M-80 COMPILATION
```

```
ISIS-II PL/M-80 V3.1 COMPILATION OF MODULE RESULTSMODULE
OBJECT MODULE PLACED IN :F1:RESULT.OBJ
COMPILER INVOKED BY:  PLM80 :F1:RESULT.PLM IXREF DEBUG DATE (3 OCT 78)


  1          RESULTS$MODULE: DO;

  2   1      TTYRES: PROCEDURE EXTERNAL;
  3   2        END TTYPES;

  4   1      COMPOSITE  PROCEDURE EXTERNAL;
  5   2                END COMPOSITE;

  6   1      COMMENT: PROCEDURE EXTERNAL;
  7   2            END COMMENT;

  8   1      COUT: PROCEDURE (LTR) EXTERNAL;
  9   2        DECLARE LTR BYTE;
 10   2        END COUT;

 11   1      PRINT: PROCEDURE (POINTER) EXTERNAL;
 12   2         DECLARE POINTER ADDRESS;
 13   2       END PRINT;

 14   1      PRNTNUM: PROCEDURE EXTERNAL;
 15   2       END PRNTNUM;

 16   1      DECLARE (RIFLE, FILE) BYTE EXTERNAL;
 17   1      DECLARE  CR LITERALLY '0DH', LF LITERALLY '0AH';
 18   1      DECLARE SCORE (5) STRUCTURE(MISS BYTE, HIT BYTE, LOW BYTE, LOW$RIGHT BYTE,
                 RIGHT BYTE, HIGH$RIGHT BYTE, HIGH BYTE, HIGH$LEFT BYTE,
                 LEFT BYTE, LOW$LEFT BYTE, ERROR BYTE, TURKEY BYTE,
                 TARGET$IGNORED BYTE) EXTERNAL;
 19   1      DECLARE DECIMAL(3) BYTE PUBLIC;
 20   1      DECLARE (I,Z) BYTE,
                   (SUM$SHOTS, NEAR$MISSES) BYTE PUBLIC;


 21   1      DECLARE ADDER(5) STRUCTURE(J(13) BYTE) EXTERNAL;
 22   1      DECLARE SPEED(5) STRUCTURE(SHOTS BYTE, TIME$SUM ADDRESS) EXTERNAL;
 23   1      DECLARE AVG$TIME ADDRESS PUBLIC;

 24   1      CONVRT: PROCEDURE(HEX);
 25   2       DECLARE HEX BYTE;
 26   2       DO I=0 TO 2;
 27   3       DECIMAL(2-I)= HEX MOD 10 + 30H;
 28   3       HEX = HEX / 10;
 29   3        END;
 30   2       END CONVRT;

 31   1      DECLARE RIFLE$ID(8) BYTE DATA(7,'RIFLE: ');
 32   1      DECLARE TOTAL$SHOTS(14) BYTE DATA(13,'TOTAL SHOTS: ');
 33   1      DECLARE RIFLE$HIT(7) BYTE DATA(6,'HITS: ');
 34   1      DECLARE RIFLE$MISS(9) BYTE DATA(8,'MISSES: ');
 35   1      DECLARE RIFLE$LOW(7) BYTE DATA(6,'LOWS: ');
 36   1      DECLARE RIFLE$LOW$RIGHT(13) BYTE DATA(12,'LOW RIGHTS: ');
```

```
37  1    DECLARE RIFLE$RIGHT(9) BYTE DATA(8,'RIGHTS: ');
38  1    DECLARE RIFLE$HIGH$RIGHT(14) BYTE DATA(13,'HIGH RIGHTS: ');
39  1    DECLARE RIFLE$HIGH(8) BYTE DATA(7,'HIGHS: ');
40  1    DECLARE RIFLE$HIGH$LEFT(13) BYTE DATA(12,'HIGH LEFTS: ');
41  1    DECLARE RIFLE$LEFT(8) BYTE DATA(7,'LEFTS: ');
42  1    DECLARE RIFLE$LOW$LEFT(12) BYTE DATA(11,'LOW LEFTS: ');
43  1    DECLARE RIFLE$TURKEY(12) BYTE DATA(11,'NO TARGET: ');
44  1    DECLARE RIFLE$TARGET$IGNORED(18) BYTE DATA(17,'TARGETS IGNORED: ');
45  1    DECLARE BLANK(3) BYTE DATA(2,CR,LF);
46  1    DECLARE HOW$MANY$SHOTS(18) BYTE DATA(17,'TARGETS SHOT AT: ');
47  1    DECLARE AVERAGE$TIME(15) BYTE DATA(14,'AVERAGE TIME: ');
48  1    DECLARE UNITS(8) BYTE DATA(7,'SECONDS');
49  1    DECLARE YOUR$SCORE (18) BYTE DATA (17,'YOUR RESULTS ARE');

50  1    DECLARE NAME(5) STRUCTURE(LETTER(9) BYTE) EXTERNAL,
                 DATE (11) BYTE EXTERNAL,
                 ID$NUMBER (6) BYTE EXTERNAL,
                 ID$FLAG BYTE EXTERNAL;

51  1    PRESENT$RESULTS: PROCEDURE PUBLIC;

52  2    DISABLE;

53  2     CALL TTYRES;         /* RESET FOR TTY OUTPUT SEE CONSOL MODULE */

54  2     CALL PRINT(.BLANK);
55  2     CALL PRINT(.BLANK);

56  2     IF ID$FLAG THEN DO;
58  3     CALL PRINT(.DATE);
59  3     CALL PRINT(.ID$NUMBER);
60  3      END;

61  2      CALL PRINT(.BLANK);
62  2      CALL PRINT(.BLANK);

63  2    ONE$RIFLE$RESULTS: DO RIFLE=1 TO 5;

64  3    IF SPEED(RIFLE-1).SHOTS <> 0 THEN
65  3    TYPE$IT: DO;

66  4     CALL PRINT(.BLANK);

67  4     CALL PRINT(.RIFLE$ID);
68  4     CALL COUT(RIFLE+30H);

69  4      CALL PRINT(.BLANK);
70  4      CALL PRINT(.BLANK);

71  4    IF ID$FLAG THEN
72  4      CALL PRINT(.NAME(RIFLE-1));
73  4     CALL PRINT(.YOUR$SCORE);

74  4     CALL PRINT(.BLANK);
75  4     CALL PRINT(.BLANK);

76  4     FILE=RIFLE-1;
```

```
 77   4        CALL PRINT(.TOTAL$SHOTS);

 78   4        SUM$SHOTS = 0;
 79   4       SUM: DO Z=0 TO 11;
 80   5        SUM$SHOTS = SUM$SHOTS + ADDER(FILE).J(Z);
 81   5         END SUM;

 82   4        NEAR$MISSES = 0;
 83   4       SUM2: DO Z = 2 TO 9;
 84   5        NEAR$MISSES = NEAR$MISSES + ADDER(FILE).J(Z);
 85   5         END SUM2;

 86   4        CALL CONVRT(SUM$SHOTS);
 87   4        CALL PRNTNUM;

 88   4        CALL PRINT(.RIFLE$HIT);
 89   4        CALL CONVRT(SCORE(FILE).HIT);
 90   4        CALL PRNTNUM;

 91   4        CALL PPINT(.RIFLE$MISS);
 92   4        CALL CONVRT(SCORE(FILE).MISS);
 93   4        CALL PRNTNUM;

 94   4        CALL PRINT(.RIFLE$LOW);
 95   4        CALL CONVRT(SCORE(FILE).LOW);
 96   4        CALL PRNTNUM;

 97   4        CALL PRINT(.RIFLE$LOW$RIGHT);
 98   4        CALL CONVRT(SCORE(FILE).LOW$RIGHT);
 99   4        CALL PRNTNUM;

100   4        CALL PRINT(.RIFLE$RIGHT);
101   4        CALL CONVRT(SCORE(FILE).RIGHT);
102   4        CALL PRNTNUM;

103   4        CALL PRINT(.RIFLE$HIGH$RIGHT);
104   4        CALL CONVRT(SCORE(FILE).HIGH$RIGHT);
105   4        CALL PRNTNUM;

106   4        CALL PRINT(.RIFLE$HIGH);
107   4        CALL CONVRT(SCORE(FILE).HIGH);
108   4        CALL PRNTNUM;

109   4        CALL PRINT(.RIFLE$HIGH$LEFT);
110   4        CALL CONVRT(SCORE(FILE).HIGH$LEFT);
111   4        CALL PRNTNUM;

112   4        CALL PRINT(.RIFLE$LEFT);
113   4        CALL CONVRT(SCORE(FILE).LEFT);
114   4        CALL PRNTNUM;

115   4        CALL PRINT(.RIFLE$LOW$LEFT);
116   4        CALL CONVRT(SCORE(FILE).LOW$LEFT);
117   4        CALL PRNTNUM;

118   4        CALL PRINT(.RIFLE$TURKEY);
```

```
119   4      CALL CONVRT(SCORE(FILE  TURKE?);
120   4      CALL PRNTNUM;

121   4      CALL PRINT( RIFLE$TARGET$IGNORED);
122   4      CALL CONVRT(SCORE(FILE) TARGET$IGNORED);
123   4      CALL PRNTNUM;

124   4      CALL PRINT( HOW$MANY$SHOTS);
125   4      CALL CONVRT(SPEED(FILE) SHOTS);
126   4      CALL PRNTNUM;

127   4      CALL PRINT( AVERAGE$TIME);
128   4      IF (Z = SPEED(FILE) SHOTS)=0 THEN Z=1;
130   4      AVG$TIME = (SPEED(FILE) TIME$SUM/20)/Z;
131   4      CALL CONVRT(LOW(AVG$TIME));
132   4      IF(Z =DECIMAL(0)) <> 30H THEN CALL COUT(Z);
134   4      CALL COUT(DECIMAL(1)
135   4      CALL COUT(2EH);     /* PERIOD OR DECIMAL POINT */
136   4      CALL COUT(DECIMAL(2))
137   4      CALL COUT(20H);
138   4      CALL PRINT( UNITS)
139   4      CALL COUT(CR);
140   4      CALL COUT(LF);

141   4      CALL PRINT( BLANK)
142   4      CALL COMMENT;     /* COMMENT AS TO REACTION TIME */

14    4      CALL PRINT( BLANK);
            /***************************************************************

              COMPOSITE IS EASY TO CHANGE. IT'S IN MODULE "FINAL"

            ***************************************************************/

14    4      CALL COMPOSITE;     /* THE COMPOSITE SCORE IS INITIALLY: =
                                   100*(HITS/SHOTS) + 60*(NEAR MISSES/SHOTS) +
                                   10*(TIME CREDIT FROM PROCEDURE "COMMENT", ABOVE)
                                   - 2*(NUMBER OF TARGETS IGNORED) */

14    4      CALL PRINT( BLANK)

14    4       END TYPE$1;

14    3       END ONE$RIFLE$RESULTS;

14    2      ENABLE;

14    2       END PRESENT$RESULTS;

15    1      END RESULTS$MODULE;


MODULE INFORMATION

     CODE AREA SIZE     = 0491H   1??9D
     VARIABLE AREA SIZE = 000AH     10D
```

```
    MAXIMUM STACK SIZE = 0006H      6D
    2'5 LINES READ
    0 PROGRAM ERROR(S)

END OF PL/M-80 COMPILATION
```

```
ISIS-II PL/M-80 V3.1 COMPILATION OF MODULE FINALMODULE
OBJECT MODULE PLACED IN :F1:FINAL.OBJ
COMPILER INVOKED BY:  PLM80 :F1:FINAL.PLM IXREF DEBUG DATE (25 JUN 79)


   1          FINAL$MODULE: DO;
   2   1      DECLARE SPEED(5) STRUCTURE(SHOTS BYTE, TIME$SUM ADDRESS) EXTERNAL,
                  (FILE, RIFLE, SUM$SHOTS, NEAR$MISSES) BYTE EXTERNAL,
                  N BYTE, AVG$TIME ADDRESS EXTERNAL,
                  SCORE(5) STRUCTURE(MISS BYTE, HIT BYTE, LOW BYTE, LOW$RIGHT BYTE,
                                   RIGHT BYTE, HIGH$RIGHT BYTE, HIGH BYTE,
                                   HIGH$LEFT BYTE, LEFT BYTE, LOW$LEFT BYTE,
                                   ERROR BYTE, TUPKEY BYTE, TARGET$IGNORED BYTE)
                                   EXTERNAL,
                  FAST (42) BYTE DATA (41, 'MAN!! YOU''RE THE FASTEST SHOT IN THE WEST'),
                  GOOD (25) BYTE DATA (24, 'HEY! YOU''RE PRETTY QUICK'),
                  FAIR (38) BYTE DATA (37, 'OH WELL! THERE''S HOPE IF YOU SPEED UP'),
                  POOR (30) BYTE DATA (29, 'SORRY, BUT YOU''RE PRETTY SLOW'),
                  CR LITERALLY '0DH', LF LITERALLY '0AH',
                  (TIME$CREDIT, N) BYTE;

   3   1      COUT: PROCEDURE (LTR) EXTERNAL;
   4   2        DECLARE LTR BYTE;
   5   2        END COUT;

   6   1      PRINT: PROCEDURE (POINTER) EXTERNAL;
   7   2          DECLARE POINTER ADDRESS;
   8   2                  END PRINT;

   9   1      COMMENT: PROCEDURE PUBLIC;
  10   2        IF AVG$TIME <= 5 THEN
       2        DO;
       3          CALL PRINT(.FAST);
       3          TIME$CREDIT = 3;
       3          END;
       2        ELSE IF AVG$TIME <= 9 THEN
       2         DO;
       3          CALL PRINT(.GOOD);
       3          TIME$CREDIT = 2;
       3          END;
       2        ELSE IF AVG$TIME <= 13 THEN
       2          DO;
       3          CALL PRINT(.FAIR);
       3          TIME$CREDIT = 1;
       3          END;
       2        ELSE  DO;
       3          CALL PRINT(.POOR);
       3          TIME$CREDIT = 0;
       3          END;
       2        END COMMENT;

       1      HX2AS: PROCEDURE(HEX$ADR, DEC$ADR) PUBLIC;
       2      DECLARE(HEX$ADR, DEC$ADR) ADDRESS,
                  HEX BASED HEX$ADR ADDRESS,
                  DECIMAL BASED DEC$ADR (5) BYTE,
                  (N,M) BYTE
```

```
32   2        DO N = 0 TO 4;
33   3         M=4-N;
34   3         DECIMAL(M) = HEX MOD 10 + 30H;
35   3         HEX = HEX/10;
36   3         END;
37   2        N=0;
38   2        DO WHILE DECIMAL(N) = 30H AND N<5;
39   3         DECIMAL(N) = 20H;                /* REPLACE LEADING ZEROS WITH SPACES */
40   3         N = N + 1;
41   3         END;
42   2        END HX2AS;

43   1       COMPOSITE: PROCEDURE PUBLIC;
44   2        DECLARE COMP(24) BYTE DATA(23,'YOUR OVERALL SCORE IS: '),
                     OVERALL ADDRESS,
                     DEC$NUM (5) BYTE;
45   2        OVERALL = 100*(SCORE(FILE).HIT)/SUM$SHOTS + 60*NEAR$MISSES/SUM$SHOTS
                      + 10*TIME$CREDIT - 2*(SCORE(FILE).TARGET$IGNORED);
46   2        CALL PRINT(.COMP);

47   2       IF OVERALL < 0F00H THEN DO;  /* I.E. CHECK FOR NEGATIVE SCORE */
49   3        CALL HX2AS(.OVERALL,.DEC$NUM);
50   3         DO N = 0 TO 4;
51   4         CALL COUT(DEC$NUM(N));
52   4          END;
53   3        END;


54   2       CALL COUT(CR);
55   2       CALL COUT(LF);
56   2       CALL COUT(LF);
57   2        END COMPOSITE;

58   1       END FINAL$MODULE;


MODULE INFORMATION:

     CODE AREA SIZE     = 0229H    553D
     VARIABLE AREA SIZE = 0010H     16D
     MAXIMUM STACK SIZE = 0008H      8D
     85 LINES READ
     0 PROGRAM ERROR(S)

END OF PL/M-80 COMPILATION
```

ISIS II PL/M-80 V1.1 COMPILATION OF MODULE INTERRUPT7
OBJECT MODULE PLACED IN :F1:INTER.OBJ
COMPILER INVOKED BY: PLM80 :F1:INTER.PLM XREF DEBUG DATE (3 OCT 78)

```
            $NOINTVECTOR

            INTERRUPT7: DO;

   1        DECLARE TRAIN BYTE EXTERNAL
               ADDCW2 LITERALLY '0D8H',  /* ADDRESS TO WHICH WE SEND THE FOLLOWING
                                            NON-SPECIFIC END OF INTERRUPT  */
               OCW2E LITERALLY '20H';    /* THE NON-SPECIFIC EOI, SEE PAGE 3-108
                                            AND PAGE 3-100 */

   1        INTERRUPT$ROUTINE: PROCEDURE INTERRUPT 7 PUBLIC;
   2         TRAIN=0;            /* PROGRAM WILL CALL FOR RESULTS TO BE TYPED OUT */
   2         OUTPUT(ADDCW2) = OCW2E;
   2         END INTERRUPT$ROUTINE;

   1        END INTERRUPT7;
```

MODULE INFORMATION:

```
     CODE AREA SIZE     = 0013H     19D
     VARIABLE AREA SIZE = 0000H      0D
     MAXIMUM STACK SIZE = 0000H      0D
     17 LINES READ
     0 PROGRAM ERROR(S)
```

END OF PL/M-80 COMPILATION

APPENDIX D

UPI-41 PROGRAM

```
AS M48 :F1:UPI41.SRC MA ROFILE DEBUG M 041 TITLE('18 JAN 79')

I IS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2 0            PAGE    1
18 JAN 79

 LOC  OBJ          SEQ          SOURCE STATEMENT

                        ;    ASSEMBLY LANGUAGE PROGRAM WRITTEN FOR THE UPI-41
                        ;    (UNIVERSAL PERIPHERAL INTERFACE-41) DURING THE
                        ;    SUMMER TERM OF ACADEMIC YEAR 77-78 BY THOMAS J
                        ;    RIORDAN WHILE WORKING AS A GRADUATE ASSISTANT
                        ;    FOR DR HERBERT C. TOWLE AT THE NAVAL TRAINING
                        ;    EQUIPMENT CENTER (NTEC) IN ORLANDO FLORIDA.
                        ;
                        ;
                        ;    THE PROGRAM ACCEPTS A PARALLEL DATA TRANSFER FROM
                        ;    AN OUTPUT PORT (8255) OF AN INTEL SBC-80/20-4
                        ;    SINGLE BOARD COMPUTER SYSTEM. THE DATA WORD IS
                        ;    DECODED TO OBTAIN A REFERENCE COLUMN ON THE FACE
                        ;    OF AN ADM CRT. THE CRT CURSOR IS THEN POSITIONED
                        ;    IN THAT COLUMN. THE DATA WORD IS FURTHER DECODED
                        ;    TO OBTAIN THE ADDRESS IN ROM OF A TEXT STRING WHICH
                        ;    IS THEN SHIFTED OUT SERIALLY THROUGH AN I/O PORT
                        ;    LINE OF THE UPI-41 AT 19200 BAUD. THE PROGRAM
                        ;    IS INTERRUPT DRIVEN AND UTILIZES A FIFO STACK TO
                        ;    BALANCE OUT DISPARITIES BETWEEN THE RATE AT WHICH IT
                        ;    CAN SHIFT OUT SERIAL DATA AS COMPARED TO THE HIGHEST
                        ;    POSSIBLE RATE AT WHICH IT MUST ACCEPT PARALLEL DATA
                        ;
                        ;    THE RUNTIME CONFIGURATION OF THE UPI-41 IS AS FOLLOWS:
                        ;
                        ;    REGISTER BANK 0
                        ;
                        ;
                        ;    REGISTER 0(R0)  7 BIT ASCII CODE COUNTER
                        ;    REGISTER 1(R1)  ASCII CHAR TO BE OUTPUT
                        ;    REGISTER 2(R2)  COUNT FOR VARIABLE DELAY
                        ;    REGISTER 3(R3)  OUTPUT STRING ADDRESS
                        ;    REGISTER 4(R4)  MASK VALUE FROM LOOKUP TABLE
                        ;    REGISTER 5(R5)  BINARY CODE FOR CRT COLUMN POSITION
                        ;    REGISTER 6(R6)  COUNTER FOR STRING OUTPUT
                        ;    REGISTER 7(R7)  PARALLEL DATA TRANSFER
                        ;
                        ;    REGISTER BANK 1
                        ;
                        ;
                        ;    REGISTER 0(R0)  CURRENT DATA POINTER
                        ;    REGISTER 1(R1)  FINAL DATA POINTER
                        ;    REGISTER 2(R2)  QUEUE STATUS
                        ;    REGISTER 3(R3)  ACCUMULATOR STORAGE
                        ;    REGISTER 4(R4)  UNUSED
                        ;    REGISTER 5(R5)  CONSTANT=193D
                        ;    REGISTER 6(R6)  CONSTANT=224D
                        ;    REGISTER 7(R7)  TEMPORARY DATA WORD STORAGE
                        ;
                        ;
                        ;    PORT 1   SERIAL TRANSMISSION ON BIT 0
                        ;    PORT 2   LINES 0-4 USED AS A MASK INPUT TO INHIBIT TEXT
                        ;             STRING OUTPUT. LINE 7 USED TO ENABLE CHIP SELECT
```

```
LOC  OBJ        SEQ       SOURCE STATEMENT

                          ;
                          ;
                          ;
                          ;
0000                           ORG 0
0000 040A                      JMP     INIT     ;PRESERVE INTERRUPT VECTORS
0003                           ORG 3D           ;EXTERNAL INTERRUPT VECTOR
0003 0458                 EXTINT: JMP  INROUT   ;JUMP TO INTERRUPT ROUTINE
0007                           ORG 7D           ;TIMER INTERRUPT VECTOR
0007 046A                 TIMINT: JMP  TIINRT   ;TIMER INTERRUPT ROUTINE
000A                           ORG 10D
000A 95                   INIT CPL     F0       ;SET FLAG SO INTERRUPTS NOT ENABLED
                                                ;DURING INITIALIZATION ROUTINE
000B 9AE0                      ANL     P2,#0E0H        ;NUMBER WILL DRIVE LINES 0-4 TO GROUND IN CASE
                                                ;THE SIMULATION PGM IS GOING TO BE RUN I.E.
                                                ;THIS WILL KEEP EACH RIFLE FROM PICKING UP
                                                ;AN EXTRANEOUS SHOT DUE TO THE OUTPUT LINES
                                                ;COMING UP HIGH--80/20 8212 CLEAR WILL NOT
                                                ;HAVE BEEN DONE AT THIS POINT IN TIME--,
                                                ;LINES 5 & 6 WILL BOTH BE HIGH AS REQUIRED
                                                ;TO LET AN EXTERNAL SIGNAL CONTROL THE TAR PRES FLAG,
                                                ;BUT WILL NOT ENABLE THE CHIP SELECT WHICH
                                                ;IS TIED TO LINE 7
000D B91A                      MOV     R1,#1AH  ;ASCII CHAR TO CLEAR CRT SCREEN
000F 3430                      CALL    OUTPUT
0011 3450                      CALL    DELAY1
0013 341A                      CALL    LOCSET   ;SET UP CRT TO ACCEPT X COORD VALUE
0015 B920                      MOV     R1,#20H  ;X VALUE FOR COLUMN 1
0017 3430                      CALL    OUTPUT   ;ROUTINE TO SEND ASCII CHARACTER
0019 D5                        SEL     RB1
001A B820                      MOV     R0,#32D  ;INITIAL VALUE FOR READ MEMORY POINTER
001C B920                      MOV     R1,#32D  ;INITIAL VALUE FOR WRITE MEMORY POINTER
001E BA00                      MOV     R2,#0    ;CLEAR QUEUE STATUS REGISTER
0020 BEE0                      MOV     R6,#224D        ;224 + 32 AVAILABLE LOCATIONS IN RAM
                                                       ;= 256 => OVERFLOW
0022 BDC1                      MOV     R5,#193D        ;193 + 63(LAST RAM ADDRESS) = 256 =>
                                                       ;OVERFLOW
0024 9A60                      ANL     P2,#60H  ;ENABLE CHIP SELECT
0026 05                        EN      I        ;ENABLE EXTERNAL INTERRUPTS
0027 FA                   WAIT: MOV    A,R2     ;GET QUEUE STATUS
0028 C627                      JZ      WAIT     ;IF QUEUE EMPTY NO ACTION
                          ;
                          ;
                          ;
                          ;
                          ;
002A F0                   START: MOV   A,@R0    ;GET DATA FROM RAM LOCATION
002B AF                        MOV     R7,A     ;STORE DATA
002C CA                        DEC     R2       ;DECREMENT QUEUE STATUS REGISTER
002D FD                        MOV     A,R5     ;193 DECIMAL
002E 68                        ADD     A,R0     ;CHECK FOR LAST ACCESS BEING @ TOP OF RAM
002F 9633                      JNZ     CONT
0031 B81F                      MOV     R0,#31D  ;ONE LESS THAN BOTTOM OF RAM
0033 18                   CONT: INC    R0       ;NEXT RAM ACCESS LOCATION
0034 FF                        MOV     A,R7     ;RETRIEVE DATA
```

```
 LOC  OBJ          SEQ        SOURCE STATEMENT

 0035 C5           108             SEL   RB0
 0036 AF           109             MOV   R7,A      ;STORE DATA
 0037 4310         110             ORL   A,#10H    ;SET BIT WHICH IS HARD WIRED LOW
 0039 37           111             CPL   A
 003A 963          112             JNZ   CONTM
 003C 441          113             JMP   RIFSIM    ;IF CODE FOR RIFLE SIMULATION ROUTINE
                   114                             ;WAS SENT JUMP TO IT
 003E 8A1          115 CONTM:      ORL   P2,#1FH   ;IF SIMULATION PGM NOT BEING RUN
                   116                             ;THEN PORT 2 0-4 MUST BE INPUTS
 0040 FF           117             MOV   A,R7      ;RETRIEVE DATA
 0041 340          118             CALL  MASK      ;CHECK TO SEE IF OUTPUT DESIRED
 0043 B65          119             JF0   ESCAPE    ;IF FLAG SET WAIT FOR NEW DATA
 0045 341          120             CALL  LOCSET    ;SET UP RAM TO ACCEPT X-COORD VALUE
 0047 FD           121             MOV   A,R5      ;GET RIFLE ID FROM PROCEDURE MASK STORAGE
                   122                             ;LOCATION
 0048 341          123             CALL  TAB       ;TAB OVER TO LOCATION CORRES TO RIFLE #
 004A FF           124             MOV   A,R7      ;RETRIEVE 80/20 DATA
 004B 47           125             SWAP  A         ;PUT CODE FOR TYPE OF SHOT
                   126                             ;IN UPPER 4 BITS TO ALLOW ACCESS TO
                   127                             ;16 MEMORY LOCATIONS PER SHOT TYPE
 004C 53           128             ANL   A,#0F0H   ;MASK OUT LOW ORDER BITS
 004E AB           129             MOV   R3,A      ;STORE RELATIVE ADDRESS OF CHAR STRING
 004F E3           130             MOVP3 A,@A      ;GET STRING LENGTH
 0050 AE           131             MOV   R6,A      ;STORE COUNTER VALUE
 0051 34           132             CALL  STROUT    ;PROCEDURE TO OUTPUT ASCII STR
 0053 34           133             CALL  CRLF
 0055 D5           134 ESCAPE:     SEL   RB1       ;RETURN TO CORRECT REG BANK FOR WAIT LOOP
 0056 04           135             JMP   WAIT
                   136 ;
                   137 ;
                   138 ;
                   139 ;
                   140 ;
 0058 D5           141 INROUT:     SEL   RB1       ;INTERRUPT REG BANK
 0059 AB           142             MOV   R3,A      ;SAVE ACCUMULATOR
 005A FE           143             MOV   A,R6      ;2 4D
 005B 6A           144             ADD   A,R2
 005C C668         145             JZ    QUEFUL    ;CHECK FOR QUEUE FULL
 005E 1E           146             INC   R2        ;INCREMENT QUEUE STATUS REGISTER
 005F 22           147             IN    A,DBB     ;INPUT DATA
                   148                             ;FROM SR INTERRUPT STORE FF
 0060 A1           149             MOV   @R1,A     ;STORE NEW DATA
 0061 FD           150             MOV   A,R5      ;1 2D
 0062 69           151             ADD   A,R1      ;CHECK TO SEE IF STORE WAS
                   152                             ;IN LAST AVAILABLE RAM LOCATION
 0063 96           153             JNZ   CONT1     ;IF NOT THEN CONTINUE
 0065 B9 F         154             MOV   R1,#310   ;BOTTOM OF QUEUE
 0067 19           155 CONT1:      INC   R1        ;INCREMENT WRITE POINTER REG
 0068 FB           156 QUEFUL:     MOV   A,R3      ;RESTORE ACCUMULATOR
 0069 93           157             RETR            ;RETURN FROM INTERRUPT
 006A 65           158 TIINRT:     STOP  TCNT             ;PREVENT FURTHER TIMER OVERFLOW
 006B C7           159             MOV   A,PSW            ;THIS SEQUENCE OF OPERATIONS ALLOWS
 006C 07           160             DEC   A                ;THE RETURN ADDRESS WHICH WAS STORED
 006D 5307         161             ANL   A,#07H           ;ON THE STACK TO BE ALTERED SO THAT
 006F E7           162             RL    A                ;ON RETURN IT WILL NOT CONTINUE IN
```

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LOC  OBJ          SEQ        SOURCE STATEMENT

0 70 0300         163          ADD    A,#0          ;THE SAME LOOP IT WAS IN WHICH FORCED
0 72 A8           164          MOV    R0,A          ;THE INTERRUPT CALL IN THE FIRST PLACE
0 3 10            165          INC    @R0           ;PROCEDURE CAN BE FIGURED OUT BY REF
0 4 10            166          INC    @R0           ;UPI-41 MANUAL PP. 2-8,9.
0 5 2314          167          MOV    A,#LOW FAL1
0 7 54AD          168          CALL   FAIL
0 93              169          RETR
0 23F0            170 FINIS:   MOV    A,# LOW DONE          ;TEST COMPLETE MESSAGE
0 AB              171          MOV    R3,A
0 E3              172          MOVP3  A,@A
0 E AE            173          MOV    R6,A
0 3427            174          CALL   STROUT
0 1 3450          175          CALL   CRLF
    0483          176 HERE:    JMP    HERE          ;WAIT FOR RESET(EXTERNAL)
                  177 ;
                  178 ;
                  179 ;  SUBROUTINES IN FIRST PAGE OF MEMORY
                  180 ;
                  181 ;
                  182 ;
0100              183          ORG 256D
0100 01           184 MSKDAT:  DB     1D,20,40,80,160
0101 02
0102 04
0103 08
0104 10
  53E0            185 MASK:    ANL    A,#0E0H  ;MASK OUT 5 LOW ORDER BITS
  47              186          SWAP   A        ;RIFLE ID IN BITS 1,2 3
  77              187          RR     A         IN BITS 0,1,2
  AD              188          MOV    R5,A     ;STORE RIFLE CODE
  07              189          DEC    A        ;RIFLE CODE(FILE) 0-4
  6 A3            190          MOVP   A,@A     ;GET LOOKUP VALUE FOR CURRENT RIFLE
  AC              191          MOV    R4,A     ;STORE VALUE
  0A              192          IN     A,P2     ;GET RIFLE MASK
  5C              193          ANL    A,R4
  85              194          CLR    F0
  9613            195          JNZ    CONT2    ;JUMP IF RIFLE NOT MASKED
  95              196          CPL    F0       ;SET FLAG INDICATING MASK
  83              197 CONT2    RET              ;RETURN FROM SUBROUTINE
  17              198 TAB:     INC    A        ;CREATE CORRECT DIGIT FOR HIGH BYTE
  47              199          SWAP   A        ;PUT IN HIGH BYTE
  A9              200          MOV    R1,A
  3430            201          CALL   OUTPUT
  83              202          RET              ;RETURN FROM SUBROUTINE
  B91B            203 LOCSET:  MOV    R1,#1BH  ;ASCII ESCAPE (REF ADM MANUAL
                  204                           ;FOR CURSOR POSITIONING)
  3430            205          CALL   OUTPUT
  B930            206          MOV    R1,#30H  ;ASCII EQUALS
  3430            207          CALL   OUTPUT
  B937            208          MOV    R1,#37H  ;ROW 24 OF ADM TERMINAL
  3430            209          CALL   OUTPUT
  83              210          RE               ;RETURN FROM SUBROUTINE
  1B              211 STROUT:  INC    R3       ;GET TO LOCATION OF TEXT BEGINNING
  FB              212          MOV    A,R3      RETRIEVE PAGE 3 ADDRESS OF
                  213                            ASCII STRING
```

```
LOC  OBJ        SEQ        SOURCE STATEMENT

0129 3          214        MOVP3  A,@A      ;GET ASCII CHARACTER
012A  9         215        MOV    R1,A
012B 430        216        CALL   OUTPUT
012D E27        217        DJNZ   R5,STROUT        ;HAVE ALL CHAR BEEN OUTPUT
012F  3         218        RET              ;RETURN FROM SUBROUTINE
0130  5         219 OUTPUT: DIS   I
0131 807        220        MOV    R4,007H ;SERIAL BIT COUNTER
0133  9         221        MOV    A,R1    ;GET ASCII CHARACTER TO BE OUTPUT
0134 900        222        ANL    P1,000H ;PUT OUT START BIT
0136 A04        223        MOV    R2,004H ;SET UP DELAY LOOP LENGTH
0138 440        224        CALL   DELAY
013A  9         225 LOOP1: OUTL   P1,A    ;OUTPUT CURRENT BIT OF SERIAL CODE
013B  7         226        RR     A       ;GET NEXT BIT OF ASCII CODE
013C  0         227        NOP            ;WAIT 1 INSTRUCTION CYCLE TO COMPENSATE
                228                       ;FOR RR BEING A SINGLE CYCLE OPERATION
013D A02        229        MOV    R2,002H ;SET UP DELAY LOOP LENGTH
013F 440        230        CALL   DELAY
0141 E3A        231        DJNZ   R4,LOOP1        ;TEST FOR 7 BITS OUTPUT
0143 401        232        ORL    P1,001H  PUT OUT STOP BIT
0145 E03        233        MOV    R2,003H  SET UP DELAY LOOP LENGTH
0147 440        234        CALL   DELAY
0149 E 4C       235        JF0    NOINEN   IF IN SETUP SEGMENT DONT ENABLE INTERRUPTS
014B E          236        EN     I
014C 8          237 NOINEN RET             RETURN FROM SUBROUTINE
014D E 4D       238 DELAY  DJNZ   R2,DELAY        ;VARIABLE DELAY DEPENDING ON R2
014F 8          239        RET             RETURN FROM SUBROUTINE
0150 B 36       240 DELAY1 MOV    R1,0150H        ;NESTED DELAY LOOP, APPROX 1/4 SEC
0152 BAFF       241 DLOOP. MOV    R2,00FFH        ;
0154 3 40       242        CALL   DELAY
0156 E 52       243        DJNZ   R1,DLOOP
0158 8          244        RET
0159 F          245 PULBIT: MOV   A,R6            ;CURRENT RIFLE NUMBER
015A 0          246        DEC    A               ;CREATE POINTER FOR LOOKUP TABLE
015B A          247        MOVP   A,@A            ;GET BYTE WITH CORRECT PULSE BIT SET
015C 8          248        RET
015D B  H       249 CRLF.  MOV    R1,00AH         ;LINE FEED
015F 34 0       250        CALL   OUTPUT
0161 B  0       251        MOV    R1,00DH         ;CARRIAGE RETURN
0163 34 0       252        CALL   OUTPUT
0165 8          253        RET
0166 2          254 CHECK  CLR    A               ;TIMER STARTING COUNT FOR TIMEOUT
                255                               ;THE PROCESSOR WILL BE INTERRUPTED
                256                               ;IF THE 80/20 DOESN'T RESPOND WITHIN
                257                               ;A SPECIFIED TIME.
0167 6          258        MOV    T,A             ;LOAD TIMER
0168 5          259        STRT   T               ;START TIMER
0169 56 9       260 LOOK:  JT1    LOOK            ;UPI WILL LOOK FOR RESET UNTIL
                261                               ;TIMEOUT HAS OCCURED
016B 65         262        STOP   TCNT            ;INTERRUPT MUST NOT OCCUR
016C B90A       263        MOV    R1,010D         ;GIVE 80/20 SUFFICIENT TIME TO
016E BAFF       264 LOOPZ: MOV    R2,00FFH        ;SEND OUT VOTRAX INITIALIZATION WORDS
0170 344D       265        CALL   DELAY
0172 E96E       266        DJNZ   R1,LOOPZ
0174 D680       267        JNIBF  NOINTR          ;RESPONSE FROM 80/20?
0176 22         268        IN     A,DBB           ;BRING IN 80/20 DATA
```

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LOC  OBJ          SOURCE STATEMENT

0177 DC                  XRL    A,R4         ;IF IDENTICAL RESULT IS ZERO
0178 C684                JZ     NEXT1        ;THEN GO ON WITH TEST
017A 231A                MOV    A,# LOW FAL2
017C 54AD                CALL   FAIL
017E 2484                JMP    NEXT1
0180 2_4          NOINTR MOV    A,# LOW FAL3
0182 54 D                CALL   FAIL         ;INDICATE FAILURE
0184 B9 A         NEXT1: MOV    P1,#10D      ;GIVE 80/20 TIME TO SEND REMAINING
                                             ;PORTION OF MESSAGE
0186 BAFF         LOOPY: MOV    P2,#0FFH
0188 34 D                CALL   DELAY
018A E9 6                DJNZ   P1,LOOPY
018C 8                   RET
018D FE           RIFLOP MOV    A,R6         ;RETRIEVE RIFLE NUMBER
018E E7                  RL     A            ;CODE IN BITS 1,2,&3
018F 4 01                ORL    A,#01H       ;NO START BIT ON SERIAL OUT LINE
0191 39                  OUTL   P1,A         ;SET UP MUX
0192 FE                  MOV    A,R6         ;GET CURRENT RIFLE
0193 4                   SWAP   A            ;PUT IN HIGH BYTE
0194 E                   RL     A            ;UPPER 3 BITS
0195 4                   ORL    A,R5         ;CREATE CORRECT RETURN CODE
0196 A                   MOV    R4,A         ;TEMP STORE
0197 3 59                CALL   PULBIT       ;GET BYTE WITH CORRECT BIT SET
                                             ;FOR RIFLE TRIGGER
0199 4 40                ORL    A,#40H       ;KEEP TARGET PRESENT DOWN
019B 3A                  OUTL   P2,A         ;RISING EDGE OF TRIGGER PULSE
019C 9 40                ANL    P2,#40H      ;FALLING EDGE OF PULSE
019E 3466                CALL   CHECK
01A0 8                   RET
                  ;
                  ;  DRIVER FOR RIFLE SIMULATION AND ITS MESSAGES LOCATED
                  ;  IN FOURTH PAGE OF MEMORY
                  ;
                  ;
                  ;       THIS SEGMENT OF THE UPI-PROGRAM PROVIDES SIMULATED
                  ;       RIFLE DATA INPUT TO THE 80/20 COMPUTER. IT CHECKS
                  ;       FOR THE PROPER RETURN BYTE TO THE UPI-41 FOR THE
                  ;       SIMULATED SHOT AND INDICATES FAILURES BY A MESSAGE
                  ;       TO THE CONSOLE.  INITIALLY IT SIGNS ON AND PROMPTS
                  ;       THE USER FOR THE HARDWARE MODIFICATIONS NECESSARY.
                  ;       IF A FAILURE OCCURS THE TEST WILL CONTINUE AND OUT-
                  ;       PUTS 1 FAILURE MESSAGE FOR EACH FAILURE OCCURENCE.
                  ;       WHEN THE TEST IS COMPLETE IT PROMPTS THE USER TO
                  ;       ASK THE 80/20 FOR ITS OUTPUT
                  ;
                  ;
                  ;       THE PROGRAM IS NON-INTERRUPT DRIVEN AND INSTEAD USES
                  ;       THE INTERRUPT FLAG TO DETERMINE WHEN VALID DATA IS PRESENT
                  ;       ON THE 80/20 DATA LINES.  UPON ENTERING THE ROUTINE
                  ;       FLAG 0 IS SET SO THAT INTERRUPTS WILL NOT BE REENABLED
                  ;       WHEN THE OUTPUT ROUTINE IS CALLED.  IF THE 80/20 DOES
                  ;       NOT RESPOND AT ALL TO AN INPUT BY THE UPI-41(INDICATED
                  ;       BY THE INTERRUPT FLAG NEVER BEING SET) THE 41 TIMES
                  ;       OUT AND JUDGES THIS AS A FAILURE AND CONTINUES THE TEST.
                  ;
```

```
LOC  OBJ        SEQ       SOURCE STATEMENT

                324 ;
                325 ;     REGISTER BANK 1 IS USED FOR THE ROUTINE AND IS PREDIFINED
                326 ;     AS FOLLOWS
                327 ;
                328 ;     REGISTER 0  UNUSED
                329 ;     REGISTER 1  OUTER LOOP OF DELAY COUNTER
                330 ;     REGISTER 2  INNER LOOP OF DELAY COUNTER
                331 ;     REGISTER 3  DELAY COUNTER
                332 ;     REGISTER 4  EXPECTED RETURN DATA FROM 80/20
                333 ;     REGISTER 5  TEMP STORAGE
                334 ;     REGISTER 6  5 RIFLE LOOP COUNTER AND CURRENT RIFLE
                335 ;     REGISTER 7  16 SHOT POSSIBILITIES LOOP COUNTER
                336 ;                 AND CURRENT SHOT TYPE
                337 ;
                338 ;     THE BOTTOM 5 LINES OF PORT TWO FUNCTION AS THE RIFLE
                339 ;     TRIGGERS INSTEAD OF AS THE MASK INPUTS.
                340 ;
                341 ;     LINE SIX OF PORT TWO IS THE TARGET PRESENT SIGNAL
                342 ;
                343 ;     PORT 1 LINES 4-7 SERVE AS THE SHOT TYPE INPUT LINES FOR
                344 ;     THE 80/20.
                345 ;
                346 ;
0200            347       ORG 512D               ; PAGE 2
                348 ;
0200 03         349 SHT OD: DB    3,2,4,3,6,0,5,4
0201 02
0202 04
0203 0
0204 06
0205 00
0206 05
0207 04
0208 08         350       DB    8,9,0,2,7,8,6,1
0209 09
020A 00
020B 02
020C 07
020D 08
020E 06
020F 01
                351 ;
                352 ;
0210 85         353 RIFLIN: CLR   F0         ;WHILE F0 IS ALREADY SET AT THIS POINT
                354                          ;THIS ADDS A LITTLE CLARITY, THE POINT
                355                          ;IS THAT INTERRUPTS CANNOT BE REENABLED
0211 95         356       CPL   F0           ;WHEN THE SERIAL OUTPUT ROUTINE IS ENTERED
                357
0212 23C0       358       MOV   A,#0C0H      ;
0214 3A         359       OUTL  P2,A         ;DISALLOW FURTHER INTERRUPT REQUESTS
                360                          ;OR INTERRUPT FLAG SETS BY DESELECTING
                361                          ;THE CHIP  TARGET FLAG DOWN AND TRIGGERS DOWN,
                362                          ;AND TAR PRES CONTROL SET FOR UPI-41 CONTROL
0215 15         363       DIS   I            ;WHEN CHIP RESELECTED INTERRUPTS WILL
                364                          ;BE CHECKED THROUGH THE INT. FLAG
```

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LOC  OBJ         SEQ         SOURCE STATEMENT

0216 25           365         EN      TCNTI           ;TIMER INTERRUPT IS USED AS A TIMEOUT
                  366                                 ;FOR SEARCH ROUTINES
0217 B91A         367         MOV     R1,#1AH         ;CLEAR THE CRT SCREEN & HOME CURSOR
0219 3430         368         CALL    OUTPUT
021B 3450         369         CALL    DELAY1          ;ALLOW CRT TIME TO CLEAR
021D 345D         370         CALL    CRLF            ;SPACE DOWN THREE LINES
021F 345D         371         CALL    CRLF            ;
0221 345D         372         CALL    CRLF            ;
0223 23D0         373         MOV     A,#LOW SIGNON   ;ADDRESS OF SIGN ON MESSAGE
0225 AB           374         MOV     R3,A            ;STORE STRING ADDRESS
0226 E3           375         MOVP3   A,@A            ;GET STRING LENGTH
0227 AE           376         MOV     R6,A            ;STORE STRING LENGTH
0228 3427         377         CALL    STROUT          ;SEND STRENGTH
022A 345D         378         CALL    CRLF            ;CARRIAGE RETURN LINE FEED
022C 345D         379         CALL    CRLF
022E 23E0         380         MOV     A,#LOW PROMPT   ;PROMPT MESSAGE
0230 AB           381         MOV     R3,A            ;STORE STRING ADDRESS
0231 E3           382         MOVP3   A,@A            ;
0232 AE           383         MOV     R6,A            ;
0233 3427         384         CALL    STROUT          ;
0235 345D         385         CALL    CRLF            ;
0237 3450         386         CALL    DELAY1          ;WAIT FOR 80/20 TO TYPE OUT LET'S START.
0239 3450         387         CALL    DELAY1
023B 3450         388         CALL    DELAY1
023D D5           389 TEST:   SEL     RB1
023E 9A00         390         ANL     P2,#00H         ;REENABLE CHIP SELECT AND PUT TARGET
                  391                                 ;FLAG UP.
0240 BE05         392 RLOOP5: MOV     R6,#05H         ;INITIALIZE RIFLE NUMBER AND LOOP
                  393                                 ;COUNTER FOR 5 TIMES THROUGH
0242 BF10         394 RLOOP1: MOV     R7,#16          ;INITIALIZE SHOT TYPE AND LOOP
                  395                                 ;COUNTER FOR 16 TIMES THROUGH
0244 54CD         396 RLOOP2: CALL    SMLOOF          ;RIFLE SIMULATION SUBROUTINE
0246 EF44         397         DJNZ    R7,RLOOP2       ;ALL DATA POSSIBILITIES DONE?
0248 EE42         398         DJNZ    R6,RLOOP1       ;DONE?
024A 8A40         399         ORL     P2,#40H         ;TARGET PRESENT DOWN
024C BB05         400         MOV     R3,#5D          ;WAIT 1 SEC REQUIRED BEFORE NEW TAR
024E 3450         401 LOOPK:  CALL    DELAY1          ;CAN APPEAR
0250 EB4E         402         DJNZ    R3,LOOPK
0252 9A00         403 TOLATE: ANL     P2,#00H         ;TARGET PRESENT UP
0254 BAFF         404         MOV     R2,#0FFH        ;MAKE SURE 80/20 SEES FLAG
0256 344D         405         CALL    DELAY
0258 8A40         406         ORL     P2,#40H         ;TARGET PRESENT DOWN
025A BAFF         407         MOV     R2,#0FFH        ;GIVE 80/20 CHANCE TO RESPOND
025C 344D         408         CALL    DELAY
025E BE05         409         MOV     R6,#5           ;RIFLE COUNTER
0260 BD0A         410         MOV     R5,#0AH         ;CODE FOR MISS-TOO LATE
0262 3480         411 LOOPC:  CALL    RIFLOP          ;SUBROUTINE WHICH FIRES SHOT FOR CURRENT
                  412                                 ;RIFLE, CHECKS FOR RESET TO EXTERNAL FF,
                  413                                 ;AND CHECKS FOR CORRECT MESSAGE SENT BACK
                  414                                 ;BY 80/20.
0264 EE62         415         DJNZ    R6,LOOPC        ;DONE?
0266 BB05         416         MOV     R3,#5D          ;WAIT 1 SEC FEQ FOR NEW TAR APPEARANCE
0268 3450         417 LOOPL:  CALL    DELAY1
026A EB68         418         DJNZ    R3,LOOPL
026C BE05         419 TARIUN: MOV     R6,#5           ;RIFLE COUNTER
```

```
LOC  OBJ         SEQ        SOURCE STATEMENT

026E 3450         20 LOOPD:  CALL   DELAY1
0270 9A00         21         ANL    P2,#0H         ;TARGET PRESENT UP
0272 BAFF         22         MOV    R2,#FFH        ;GIVE 80/20 TIME TO RESPOND
0274 3440        423         CALL   DELAY
0276 3459        424         CALL   PULBIT
0278 43E0        425         ORL    A,#11100000B   ;TOP 3 BITS MUST BE ZERO AFTER CPL
027A 37          426         CPL    A              ;ALL BUT ONE RIFLE WILL SHOOT
027B 3A          427         OUTL   P2,A           ;RISING EDGE OF TRIGGERS
027C 9901        428         ANL    P1,#01H        ;HAVE DATA SET FOR HITS, NO START BIT
027E 9A00        429         ANL    P2,#30         ;FALLING EDGE
0280 3450        430         CALL   DELAY1
0282 3450        431         CALL   DELAY1         ;GIVE 80/20 TIME TO SEND ALL MESSAGES
0284 22          432         IN     A,DBB          ;CLEAR IBF FLAG WHICH THE 80/20 SENT 4
                 433                               ;PULSES TO.
02‥ 8A40         434         ORL    P2,#40H        ;TARGET PRESENT DOWN
02E‥ BB06        435         MOV    R3,#6D         ;DELAY OVER 1 SECOND SO THAT UPI WILL BE
02E‥ 3450        436 LOOPK:  CALL   DELAY1         ;CERTAIN TO HAVE RECEIVED INTER PULSE
02EB EB89        437         DJNZ   R3,LOOPK
02‥ D690         438         JNIBF  NOINT          ;IF NO INT PULSE INDICATE A FAILURE
02‥ FE           439         MOV    A,R6           ;GET CURRENT RIFLE
02‥ E7           440         RL     A              ;DATA IN BITS 3,2,1
02‥ 47           441         SWAP   A              ;IN BITS 7,6,5.
02‥ 430C         442         ORL    A,#CH          ;C IS ADDRESS OF "TARGET IGNORED."
0294 AC          443         MOV    R4,A           ;STORE
029‥ 22          444         IN     A,DBB          ;INPUT DATA
02‥ DC           445         XRL    A,R4           ;IF RESULT IS ZERO THEN BYTES IDENTICAL
0297 C6A1        446         JZ     CONTA
0299 231A        447         MOV    A,# LOW FAL2   ;PREPARE TO CALL DATA FAILURE ROUT.
029B 449F        448         JMP    CONTB
029D 2324        449 NOINT:  MOV    A,# LOW FAL3
029F 54AD        450 CONTB:  CALL   FAIL
02A1 EE6E        451 CONTA:  DJNZ   R6,LOOPD
‥A‥ BE05         452 MINOTR: MOV    R6,#5          ;5 RIFLES
‥ BD0B           453         MOV    R5,#0BH        ;CODE FOR NO TARGET
‥A‥ 3480         454 LOOPJ:  CALL   RIFLOP
‥A9 EEA7         455         DJNZ   R6,LOOPJ
‥AB 447A         456         JMP    FINIS
                 457 ;
                 458 ;
                 459 ;
                 460 ;
                 461 ;
                 462 ;
                 463 ;
                 464 ;
02AD C5          465 FAIL:   SEL    RB0            ;SEND RIFLE IDENTIFIER TO CRT
02AE AF          466         MOV    R7,A           ;STORE FAILURE TYPE
02AF D5          467         SEL    RB1
02B0 FE          468         MOV    A,R6           ;GET CURRENT RIFLE
02B1 C5          469         SEL    RB0
02B2 E7          470         RL     A              ;MUL BY TWO TO ACCESS TWO LOCATIONS AT A TIME
02B3 43F0        471         ORL    A,#F0H         ;ACCESS FXH
0‥B5 AD          472         MOV    R5,A           ;TEMP STORE
0‥B6 A3          473         MOVP   A,@A           ;GET RIFLE IDENTIFIER
0‥B7 A9          474         MOV    R1,A
```

```
 LOC  OBJ         SOURCE STATEMENT

 02B8 3430                CALL   OUTPUT
 02BA FD                  MOV    A,R5          ;RETRIEVE POINTER
 02BB 17                  INC    A             ;ACCESS NEXT LOCATION
 02BC A3                  MOVP   A,@A          ;GET REST OF IDENTIFIER
 02BD A9                  MOV    R1,A
 02BE 3430                CALL   OUTPUT
 02C0 B920                MOV    R1,#020H      ;ASCII SPACE
 02C2 3430                CALL   OUTPUT
 02C4 FF                  MOV    A,R7          ;RETRIEVE FAILURE TYPE
 02C5 AB                  MOV    R3,A          ;NOW SEND OUT FAILURE TYPE TO CRT
 02C6 E3                  MOVP3  A,@A          ;
 02C7 AE                  MOV    R6,A          ;
 02C8 3427                CALL   STROUT        ;
 02CA 345D                CALL   CRLF          ;
 02CC 93                  RETR                 ;
 02CD FF          SMLOOP: MOV    A,R7          ;GET SHOT TYPE
 02CE 07                  DEC    A
 02CF 37                  CPL    A
 02D0 530F                ANL    A,#0FH        ;SHOT DATA LINES HAVE INVERTING DRIVERS
 02D2 47                  SWAP   A             ;SHOT TYPE DATA LINES ARE P1 4-7
 02D3 AD                  MOV    R5,A          ;TEMP STORE
 02D4 FE                  MOV    A,R6          ;GET CURRENT RIFLE
 02D5 E7                  RL     A             ;PUT CODE IN BITS 1,2,&3
 02D6 4D                  ORL    A,R5          ;OR SHOT TYPE & RIFLE # TOGETHER
 02D7 4301                ORL    A,#01H        ;DON'T SEND OUT A START BIT
 02D9 39                  OUTL   P1,A          ;SET UP SHOT DATA LINES AND
                                               ;INPUTS TO THE MULTIPLEXER.
 02DA FF                  MOV    A,R7          ;RETRIEVE SHOT TYPE
 02DB 07                  DEC    A
 02DC A3                  MOVP   A,@A          ;GET CORRECT RETURN CODE FOR COMPARISON
 02DD AD                  MOV    R5,A          ;STORE
 02DE FE                  MOV    A,R6          ;GET CURRENT RIFLE
 02DF 47                  SWAP   A             ;PUT CODE IN UPPER 4 BITS
 02E0 E7                  RL     A             ;UPPER 3 BITS
 02E1 4D                  ORL    A,R5          ;CREATE EXPECTED RETURN CODE
 02E2 AC                  MOV    R4,A          ;STORE
 02E3 345[illegible]      CALL   PULBIT        ;GET FROM PAGE 1 A BYTE WHICH WILL
                                               ;HAVE THE CORRECT BIT SET FOR A
                                               ;TRIGGER PULL BY THIS RIFLE
 02E5 3A                  OUTL   P2,A          ;RISING EDGE OF PULSE
 02E6 27                  CLR    A
 02E7 3A                  OUTL   P2,A          ;FALLING EDGE OF PULSE. NOTE: THIS
                                               ;MAY OR MAY NOT BE THE CASE IN REALITY
                                               ;FOR IF THE MASK SWITCH FOR THE CURRENT
                                               ;RIFLE IS ON, THEN THE ACTUAL PULSE
                                               ;WILL ONLY BE THE MUCH SHORTER PULSE(500
                                               ;NSEC) THAT THE UPI PROVIDES AS A FAST
                                               ;TURN ON FOR THE PORT BEFORE THE 50K
                                               ;PULLUP TAKES EFFECT. HERE THE 50K
                                               ;PULLUP WILL NOT PROVIDE A HIGH OUTPUT
                                               ;DUE TO THE 5K PULLDOWN AND THE OUTL
                                               ;INSRUCTION WOULD NOT BE NEEDED
                                               ;THE LOGIC 'HIGH' WILL ACTUALLY BE
                                               ; ABOUT 2.5V WHICH IS ACCEPTABLE TO THE 41
 02E8 34[illegible]       CALL   CHECK
```

```
 ?OC  OBJ        SEQ        SOUR E STA EMENT

 ?2EA 83          530        RET
                  531
                  532
  ?F2             533        ORG    ?2H
                  534
 0?F2 5231        535        DB      ?1','R?','R3' 'R4','R'
 0?F4 5232
 0 F6 5233
 0?F8 5234
 0?FA 5?35
                  536
                  537
                  538
                  539 ;
                  540 ;
                  541 ;
                  542 ;
                  543 ; STRING DATA L?CATED IN THIRD PAGE OF MEMORY
                  544 ;
                  545 ;
 0?00             546        ORG ?68
 0?00 04          547        DB     4H,'MISS          '
 0?01 4?495353
 0?05 2?202020
 0?09 20202020
 0?0D 2?2020
 ??10 0?          548        DB     3H,'HIT'
 ??11 4?4954
 ??14 0?          549 FAL1:  DB     05H,'F RES'
 ??15 4?20524?5
 ??19 5?
 031A 0?          550 FAL2   DB     05H,'F DAT'
 031B 4?20444
 0?1F 54
 0??0 0?          551        DB     3H,'LO?'
 0??1 4?4F57
 0?24 0?          552 FAL3   DB     05H,'F ?NT       '
 0??5 4?20494E
 0??9 5?202020
 0??D 202020
 0??? 0?          553        DB     9H,'LOW ?IGHT     '
 0??? 4?4F5720
 0??? 5?494748
 0??? 5?202020
 0??? 2?2020
 0??? 0?          ?54        DB     5H,'RI?HT         '
 0??1 5?494748
 0??? 5?202020
 0??? ??202020
 0??? 2?2020
 0??? 0?          ?55        DB     10D,'HIGH RI?HT
 0??? 4?494748
 0??? 2?524947
 0??? 4?542020
 0??? 2?2020
```

```
LOC  OBJ          SEQ      SOURCE STATEMENT

0360 04           556      DB      4H,'HIGH      '
0361 484 4748
0365 202 2020
0369 202 2020
036D 202020
0370 09           557      DB      9H,'HIGH LEFT     '
0371 48494748
0375 204C4546
0379 5420 020
037D 20C420
0380 04           558      DB      4H,'LEFT      '
0381 4C4 4654
0385 202 020
0389 202 2020
038D 202420
0390 08           559      DB      8H,'LOW LEFT      '
0391 4C4F5720
0395 4C454654
0399 202 2020
039D 202020
03A0 0D           560      DB      12D,'MISS-TOO LATE '
03A1 4D495353
03A5 2D544F4F
03A9 204C4154
03AD 452020
03B0 09           561      DB      9H,'NO TARGET     '
03B1 4E 2054
03B5 415 4745
03B9 542 2020
03BD 202020
03C0 0E           562      DB      14D,'TARGET IGNORED '
03C1 54415247
03C5 45 42049
03C9 47 4F52
03CD 45 20
03D0 0F           563 SIGNON: DB   15D,'RIFLE SIMULATOR'
03D1 524 464C
03D5 45  5349
03D9 40  4C41
03DD 54  52
03E0 0F           564 PROMPT: DB   15D,'STRAP IN PLACE?'
03E1 53 45241
03E5 50 0494E
03E9 20 4C41
03ED 434 3F
03F0 0F           565 DONE:   DB   15D,'  TEST COMPLETE'
03F1 20 05445
03F5 53 42043
03F9 4F4D504C
03FD 45 445
                  566      END

USER SYMBOLS
CHECK  01 5   CONT   0033   CONT1  006   CONT2  0113   CONTA  02A1   CONTB  029F   CONTM  003E   CRLF  015D
DELAY  01 D   DELAY1 0150   DLOOP  01 2  DONE   03F0   ESCAPE 0055   EXTINT 0003   FAIL   02AD   FAL1  0314
```

```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0                PAGE   13
18 JAN 79

FAL2   031A   FAL3   0324   FINIS  007A   HERE   0083   INIT   000A   INROUT 0058   LOCSET 011F   LOOK   0169
LOOP1  013A   LOOPC  0262   LOOPI  026E   LOOPJ  02A7   LOOPK  0289   LOOPL  0268   LOOPX  024E   LOOPY  0186
LOOPZ  016E   MASK   0105   MINOS  02A3   MSKIAT 0100   NEXT1  0184   NOINEN 014C   NOINT  0240   NOINTR 0180
OUTPUT 0130   PROMPT 03E0   PULSIT 0159   QUEUL  0068   RIFLOP 0180   RIFSIM 0210   RLOOP1 0242   RLOOP2 0244
RLOOPS 0240   SHTCOD 0200   SIGNON 03D0   SMLOOP 02CD   START  002A   STROUT 0127   TAB    0114   TARIGN 026C
TEST   023D   TIINRT 006A   TIMINT 0007   TOLATE 0252   WAIT   0027

ASSEMBLY COMPLETE,   NO ERRORS
```

APPENDIX E

SELF CHECK PROGRAM

```
ISIS II LOCATER ...
-LOCATE :F1:TST.TMP TO :F1:TST SYMBOLS LINES MAP PRINT(:F1:TST.PRT)

SYMBOL TABLE OF MODULE TST
READ FROM FILE :F1:TST.TMP
WRITTEN TO FILE :F1:TST

VALUE TYPE SYMBOL

      MOD  TESTMODULE
C1BFH SYM  MEMORY
C001H SYM  TEST
C001H LIN      14
C001H LIN      15
C004H LIN      16
C007H LIN      17
C00AH LIN      18
C00CH LIN      19
C010H LIN      20
C013H LIN      21
      MOD  TESTPROCMODULE
C1BFH SYM  MEMORY
C000H SYM  TSTCHECK
3900H SYM  N
C018H SYM  DONE
C01EH SYM  LEDON
3901H SYM  K
C020H SYM  FAIL
3902H SYM  J
3903H SYM  IODATA
C080H SYM  IOTEST
C014H SYM  LOWLIMIT
C016H SYM  HIGHLIMIT
3904H SYM  INITIALTIME
3906H SYM  FINALTIME
3908H SYM  ELAPSEDTIME
390AH SYM  I
C0DCH SYM  TIMERTEST
C138H SYM  USARTTEST
C018H LIN      41
C018H LIN      42
C01EH LIN      43
C01CH LIN      44
C01FH LIN      45
C020H LIN      47
C024H LIN      49
C033H LIN      50
C041H LIN      51
C045H LIN      52
C04AH LIN      53
C051H LIN      54
C05FH LIN      55
C064H LIN      56
C068H LIN      57
C072H LIN      58
C080H LIN      59
C085H LIN      60
C08CH LIN      61
C08DH LIN      65
C08DH LIN      67
C090H LIN      68
C094H LIN      69
C099H LIN      70
C09EH LIN      71
C0A3H LIN      72
C0A7H LIN      73
```

```
C0[illegible]H LIN      74
C0E1H LIN      75
C0E6H LIN      76
C0EAH LIN      77
C0EFH LIN      78
C0[illegible]4H LIN      79
C0[illegible]9H LIN      80
C0[illegible]DH LIN      81
C0[illegible]2H LIN      82
C0[illegible]7H LIN      83
C0DCH LIN      85
C0DDH LIN      90
C0DDH LIN      91
C0E0H LIN      92
C0E5H LIN      93
C0EBH LIN      94
C0F9H LIN      95
C0FEH LIN      96
C105H LIN      97
C10BH LIN      98
C117H LIN      99
C121H LIN     100
C126H LIN     101
C1[illegible]2H LIN     102
C1[illegible]7H LIN     103
C1[illegible]8H LIN     106
C138H LIN     107
C13BH LIN     108
C140H LIN     109
C143H LIN     110
C148H LIN     111
C14[illegible]H LIN     112
C151H LIN     113
C15EH LIN     114
C1[illegible]H LIN     115
      MOD   RAMTST
C1[illegible]H SYM   LOOP
C184H SYM   LOOPA
C17[illegible]H SYM   RAMFAL
C161H SYM   RAMTST
      MOD   ROMTST
C1A9H SYM   CONTZ
C194H SYM   LOOPA
C18EH SYM   ROMTST
      MOD   SBCTIM
C1B[illegible]H SYM   LOOPA
C1B5H SYM   LOOPB
C1B[illegible]H SYM   SBCTIM

MEMORY MAP OF MODULE TST
READ FROM FILE :F1 TST TMP
WRITTEN TO FILE :F1:TST
MODULE START ADDRESS 0026H

START    STOP LENGTH REL  NAME

[illegible]  C08CH    8DH   A   ABSOLUTE
[illegible]  C1BEH   132H   A   ABSOLUTE
```

```
ISIS-II PL/M-80 V3.1 COMPILATION OF MODULE TESTMODULE
OBJECT MODULE PLACED IN :F1:TESTER.OBJ
COMPILER INVOKED BY:  PLM80 :F1:TESTER.LM DEBUG IXREF DATE (12 OCT 78)

                      /* THIS TEST PROGRAM WAS WRITTEN BY TOM RIORDAN.  ITS FUNCTION
                         IS TO ACT AS THE DRIVER FOR THE TEST PROCEDURES AS CALLED */

   1          TEST$MODULE: DO;

   2    1     RAMTST: PROCEDURE EXTERNAL;
   3    2      END RAMTST;
   4    1     ROMTST: PROCEDURE EXTERNAL;
   5    2      END ROMTST;
   6    1     IO$TEST: PROCEDURE EXTERNAL;
   7    2      END IO$TEST;
   8    1     TIMER$TEST: PROCEDURE EXTERNAL;
   9    2      END TIMER$TEST;
  10    1     USART$TEST: PROCEDURE EXTERNAL;
  11    2      END USART$TEST;
  12    1     DONE: PROCEDURE EXTERNAL;
  13    2      END DONE;

  14    1     TEST: PROCEDURE PUBLIC;
  15    2         CALL RAMTST;
  16    2         CALL ROMTST;
  17    2         CALL IO$TEST;
  18    2         CALL TIMER$TEST;
  19    2         CALL USART$TEST;
  20    2         CALL DONE;
  21    2     END TEST;


  22    1     END TESTMODULE;


MODULE INFORMATION:

     CODE AREA SIZE     = 0013H     19D
     VARIABLE AREA SIZE = 0000H      0D
     MAXIMUM STACK SIZE = 0002H      2D
     24 LINES READ
     0 PROGRAM ERROR(S)

END OF PL/M-80 COMPILATION
```

```
ISIS-II PL/M 80 V3.  COMPILATION OF MODULE TESTPRC MODULE
OBJECT MODULE PLACED IN :F1:TSTPRC.OBJ
COMPILER INVOKED BY   PLM80 :F1:TSTPRC.PLM XREF DEBUG DATE (5 JUL 79)



  1          TEST$PROC$MODULE: DO;

  2    1     DECLARE TSTCHECK BYTE PUBLIC AT (0C000H) DATA(1);
             $NOLIST

 38    1     DECLARE N BYTE;

 39    1     DECLARE WORD LITERALLY 'ADDRESS';

 40    1     DECLARE DONTCARE LITERALLY '00H', FOREVER LITERALLY 'WHILE 1',
                     DIAGNOSTIC$LED LITERALLY '0E6H';
 41    1      DONE: PROCEDURE PUBLIC;
 42    2        LED$ON:
                  DO FOREVER;
 43    3               OUTPUT(DIAGNOSTIC$LED)=DONTCARE;
 44    3            END LED$ON;
 45    2      END DONE;

 46    1     DECLARE K BYTE;
 47    1     FAIL: PROCEDURE(J) PUBLIC;
 48    2     DECLARE J BYTE;
 49    2       DO K=1 TO J;
 50    3        DO N=1 TO 10;
       4          OUTPUT(DIAGNOSTIC$LED)=DONTCARE
       4          CALL SBCTIM(10);
       4          END;
 54    3          DO N=1 TO 40;
       4            CALL SBCTIM(125);
 56    4          END;
       3        END;
       2       DO N=1 TO 80;
       3        CALL SBCTIM(250);      /* WAIT 2 SECONDS THEN GO ON WITH TEST */
       3       END;
       2     END FAIL;

 62    1     DECLARE IO$FAIL LITERALLY '3';    /* 3 FLASHES FOR AN I/O FAILURE */
 63    1     DECLARE PORT1 LITERALLY '0E4H', PORT2 LITERALLY '0E5H',
                     PORT3 LITERALLY '0E6H', PORT6 LITERALLY '0EAH';
 64    1     DECLARE IODATA BYTE;
 65    1     IO$TEST: PROCEDURE PUBLIC;
 66    2      DO;
 67    3        CALL PORT$SET; /* SET UP IO PORTS 1&2 AS INPUTS 3&6 AS OUTPUTS */

 68    3        OUTPUT(PORT3)=00H;  /* PORT 3 WILL INVERT OUTPUT THEN PORT 1 WILL REINVERT IT  */
 69    3        IODATA=INPUT(PORT1);
 70    3        IF IODATA<>00H THEN
 71    3           CALL FAIL(IO$FAIL);

 72    3        OUTPUT(PORT3)=0FFH;
 73    3        IODATA=INPUT(PORT1);
 74    3        IF IODATA<>0FFH THEN
```

```
 75   3              CALL FAIL(IO$FAIL);

 76   3            OUTPUT(PORT6)=00H; /* PORT 6 INVERTS OUTPUT BUT PORT 2 WILL NOT REINVERT */
 77   3            IODATA=INPUT(PORT2);
 78   3            IF IODATA<>0FFH THEN
 79   3              CALL FAIL(IO$FAIL);

 80   3            OUTPUT(PORT6)=0FFH;
 81   3            IODATA=INPUT(PORT2);
 82   3            IF IODATA<>00H THEN
 83   3              CALL FAIL(IO$FAIL);
 84   3          END;
 85   2          END IO$TEST;

 86   1        DECLARE LOW$LIMIT WORD DATA(100)  HIGH$LIMIT WORD DATA(300);
 87   1        DECLARE TIMER$FAIL$LOW LITERALLY '4', TIMER$FAIL$HIGH LITERALLY '5';
 88   1        DECLARE (INITIALTIME,FINALTIME,ELAPSEDTIME) WORD;
 89   1        DECLARE I BYTE;
 90   1        TIMER$TEST: PROCEDURE PUBLIC;
 91   2          CALL TIMER$START; /* START TIMERS 0 AND 1 */
 92   2          CALL SBCTIM(250);  /* GIVE TIMER TIME TO BEGIN FUNCTIONING */
 93   2          INITIAL$TIME = CLOCKREAD;
 94   2            DO I=1 TO 40; /* WAIT FOR ONE SECOND */
 95   3              CALL SBCTIM(250);
 96   3            END;
 97   2            FINALTIME=CLOCKREAD;

 98   2            ELAPSEDTIME = INITIALTIME - FINALTIME;  /* COUNTERS ARE DOWN COUNTERS */
 99   2            IF ELAPSEDTIME < LOW$LIMIT THEN
100   2              CALL FAIL(TIMER$FAIL$LOW);
101   2            IF ELAPSEDTIME > HIGH$LIMIT THEN
102   2              CALL FAIL(TIMER$FAIL$HIGH);

103   2          END TIMER$TEST;

104   1        DECLARE USART$FAIL LITERALLY '6';
105   1        DECLARE USART$STATUS LITERALLY '0EDH', USART$DATA LITERALLY '0ECH';
106   1        USART$TEST: PROCEDURE PUBLIC;
107   2          CALL VOTRAX$TIMER;
108   2          CALL SBCTIM(100); /* MAKE CERTAIN TIMER HAS STARTED */
109   2          CALL VOTRAX$SET; /* SET BAUD RATE AND BIT PATTERN */
110   2          CALL SBCTIM(100);  /* MAKE CERTAIN USART HAS COMPLETED INTERNAL SETUP */
111   2          OUTPUT(USART$DATA)=10101010B; /* SEND OUT TEST PATTERN */
112   2          CALL SBCTIM(20); /* WAIT APPROX 1.04 MSEC=>USART SHOULD BE DONE */
                             /* N.B  THIS MUST BE LONG ENOUGH EVEN WITHOUT WAIT STATES */
113   2          IF NOT SHR(INPUT(USART$STATUS),2) THEN
114   2            CALL FAIL(USART$FAIL);
115   2        END USART$TEST;


116   1        END TEST$PROC$MODULE;
```

MODULE INFORMATION

    CODE AREA SIZE   0140H   333D

```
VARIABLE AREA SIZE = 000BH     11D
MAXIMUM STACK SIZE = 0004H      4D
138 LINES READ
0 PROGRAM ERROR(S)

END OF PL/M-80 COMPILATION
```

```
ASM80 :F1:RAMTST.SRC DEBUG MACROFILE TITLE('1' OCT 78')


ISIS-II 8080/8085 MACRO ASSEMBLER, V2.0        RAMTST   PAGE    1
11 OCT 78

  LOC  OBJ        SEQ         SOURCE STATEMENT

                    1          NAME    RAMTST
                    2          STKLN   0H
                    3          EXTRN   DONE
                    4          PUBLIC  RAMTST
                    5
                    6          CSEG
  0000 D1           7 RAMTST:  POP     D            ;GET RETURN ADDRESS THAT WAS PUSHED
                    8                               ;BY THE CALL AND SAVE IT IN THE DE
                    9                               ;REG PAIR.  IT WILL BE VALID IF RAM
                   10                               ;IS OKAY, AND UNUSED OTHERWISE
  0001 0100F8      11          LXI     B,0F800H     ;INCREMENTING THIS VALUE AND CHECKING
                   12                               ;FOR OVERFLOW WILL INDICATE WHEN TEST
                   13                               ;IS FINISHED.
  0004 210038      14          LXI     H,3800H      ;START OF RAM
  0007 AF          15 LOOP:    XRA     A
  0008 77          16          MOV     M,A          ;STORE 00H AT LOCATION
  0009 7E          17          MOV     A,M          ;READ 00 FROM SAME LOCATION?
  000A B7          18          ORA     A            ;SET FLAGS
  000B C21E00   C  19          JNZ     RAMFAL       ;IF 00 NOT READ BACK JUMP TO FAILURE ROUTINE
  000E 2F          20          CMA                  ;IF PASSES THEN ACCUM=FFH
  000F 77          21          MOV     M,A          ;STORE FFH AT LOCATION
  0010 7E          22          MOV     A,M          ;READ FFH FROM SAME LOCATION?
  0011 3C          23          INR     A            ;IF FFH READ BACK ACCUM=00
  0012 C21E00   C  24          JNZ     RAMFAL       ;IF FFH NOT READ BACK JUMP TO FAIL ROUT
  0015 23          25          INX     H            ;ADDRESS NEXT MEMORY LOCATION
  0016 03          26          INX     B            ;CHECK FOR TEST COMPLETE
  0017 78          27          MOV     A,B
  0018 B7          28          ORA     A
  0019 C20700   C  29          JNZ     LOOP
  001C D5          30          PUSH    D            ;PUT RETURN ADDRESS BACK ON STACK
  001D C9          31          RET
  001E D3D6        32 RAMFAL:  OUT     0D6H         ;FLASH LED 1 TIME TO INDICATE RAM FAILURE
  0020 01E8FD      33          LXI     B,65000      ;DELAY APPROXIMATELY 1 SEC THEN JUMP TO
  0023 0B          34 LOOPA:   DCX     B            ;DONE ROUTINE.  THIS IS DONE BECAUSE THE
  0024 00          35          NOP                  ;REST OF THE TESTS CANNOT BE RUN RELIABLY
  0025 78          36          MOV     A,B          ;UNLESS THE RAM IS WORKING PROPERLY
  0026 B7          37          ORA     A            ;
  0027 C22300   C  38          JNZ     LOOPA        ;
  002A C30000   E  39          JMP     DONE
                   40          END

PUBLIC SYMBOLS
RAMTST C 0000

EXTERNAL SYMBOLS
DONE   E 0000

USER SYMBOLS
DONE   E 0000    LOOP   C 0007    LOOPA  C 0023    RAMFAL C 001E    RAMTST C 0000

ASSEMBLY COMPLETE,  NO ERRORS
```

```
ASM80 :F1:ROMTST.SRC DEBUG MACROFILE TITLE('18 JUN 79')

ISIS II 8080/8085 MACRO ASSEMBLER, V2 0         ROMTST   PAGE    1
18 JUN 79

  LOC  OBJ         SEQ        SOURCE STATEMENT

                    1         NAME    ROMTST
                    2         STKLN   0H
                    3         EXTRN   FAIL
                    4         PUBLIC  ROMTST
                    5
                    6         CSEG
                    7
  0000 210000       8 ROMTST  LXI     H,0H           ;START OF PROGRAM ROM
  0003 110008       9         LXI     D,0D000H       ;START OF TEST ROM
  0006 0E02        10 LOOPA:  MVI     C,2            ;2 FLASHES INDICATES ROM FAILURE
  0008 7E          11         MOV     A,M            ;READ PROGRAM ROM
  0009 47          12         MOV     B,A            ;SAVE BYTE
  000A EB          13         XCHG
  000B 7E          14         MOV     A,M            ;READ TEST ROM
  000C B8          15         CMP     B              ;A-B
  000D CA1B00   C  16         JZ      CONTZ          ;IF A<>B THEN FAILURE HAS OCCURED
  0010 F5          17         PUSH    PSW
  0011 C5          18         PUSH    B
  0012 D5          19         PUSH    D
  0013 E5          20         PUSH    H
  0014 CD0000   E  21         CALL    FAIL
  0017 E1          22         POP     H
  0018 D1          23         POP     D
  0019 C1          24         POP     B
  001A F1          25         POP     PSW
  001B 13          26 CONTZ   INX     D              ;NEXT ROM LOCATIONS
  001C 23          27         INX     H
  001D 7A          28         MOV     A,D
  001E EB          29         XCHG
  001F FE14        30         CPI     14H            ;IS TEST COMPLETE?
  0021 C20600   C  31         JNZ     LOOPA
  0024 C9          32         RET
                   33         END

PUBLIC SYMBOLS
ROMTST C 0000

EXTERNAL SYMBOLS
FAIL   E 0000

USER SYMBOLS
CONTZ  C 001B     FAIL    E 0000     LOOPA  C 0006     ROMTST C 0000

ASSEMBLY COMPLETE,   NO ERRORS
```

```
  M80  F1 SBCTIM SRC DEB G MACRO ILE TIT.E('23 OCT 78')

ISIS-II 8080/808 MACRO ASSEMBLE   V2 0        SBCTIM   PAGE    1
23 OCT 78

  LOC  OBJ        SEQ        SOURCE STATEMENT

                   1          NAME    SBCTIM
                   2          STKLN   0H
                   3          PUBLIC  SBCTIM
                   4
                   5          CSEG
  0000 060A        6 SBCTIM:  MVI     B,10
  0002 78          7 LOOPB:   MOV     A,B
  0003 3D          8 LOOPA:   DCR     A
  0004 C20300   C  9          JNZ     LOOPA
  0007 0D         10          DCR     C
  0008 C20200   C 11          JNZ     LOOPB
  000B C9         12          RET
                  13          END

PUBLIC SYMBOLS
SBCTIM C 0000

EXTERNAL SYMBOLS

USER SYMBOLS
LOOPA  C 0003    LOOPB  C 0002    SBCTIM C 0000

ASSEMBLY COMPLETE,   NO ERRORS
```

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